The Impact of Sex and Menstrual Phase on Emotional Reactivity and Emotion Regulation

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BA (Hons)

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Doctor of Philosophy

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Declaration of Originality

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright. The publishers of the papers within this thesis hold the copyright for that content, and access to the material should be sought from the respective journals. The remaining non published content of the thesis may be made available for loan and limited copying and communication in accordance with the Copyright Act 1968.

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The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.

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Author 3 assisted with data collection.

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Paper 2: Women in the Midluteal Phase of the Menstrual Cycle have Difficulty Suppressing the Processing of Negative Emotional Stimuli: An Event-related Potential Study (Located in Chapter 9)

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Paper 3 (in preparation): Sex differences in the Cortical Processing of Emotion (Located in Chapter 7)

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Dedication

It is with pride and affection that I dedicate this PhD in loving memory to my late mother, Yvonne Margaret Nichols (1946-2012) and late brother, Adrian William Lusk (1984-2014), who tragically passed away during the completion of this thesis.

No words are sufficient to describe the contribution you both made to my life or how much I miss you. You provided me with unconditional love and support and taught me to work hard for the things that I aspire to achieve. You were both always so proud of my achievements and never had anything but confidence in me. I will be forever grateful to my mother who was the foundation in my life and instilled in me the value of education. You were and always will be the wind beneath my wings.

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ABSTRACT

Epidemiological research has reliably determined that women are significantly more likely to develop anxiety disorders than men, with women typically developing these disorders at twice the rate of men. While sex differences in the development and prevalence of such psychiatric conditions are established, the mechanisms underlying these differences are currently unknown. One proposed mechanism is that women exhibit greater emotional reactivity to negative emotions than men, leading to enhanced sensitivity for processing unpleasant or threatening stimuli. This pattern of responding reflects a negativity bias. An alternative explanation of the vulnerability of women in developing anxiety disorders is that women, when compared to men, have greater difficulty regulating their response to unpleasant stimuli and subsequent negative emotions. Behavioural, physiological, and neuroimaging data indicate that women are overall more responsive to emotional stimuli, particularly unpleasant stimuli, relative to men. However, previously reported sex-related differences in electrophysiological cortical activity during emotion processing, and particularly in emotion regulation, have been understudied and existing data is varied and inconsistent.

Two key theories have been developed to explain the processing of emotional information; the motivational model and the negativity bias hypothesis. The motivational model asserts that emotional (pleasant and unpleasant) stimuli require greater processing relative to neutral stimuli. In contrast, the negativity bias hypothesis proposes prioritised processing of unpleasant compared with pleasant and neutral stimuli. The current thesis was designed to investigate the

competing theoretical perspectives and possible mechanisms which may explain sex differences in psychopathologies such as anxiety disorders. This research project used high temporal resolution event-related potentials (ERPs) to investigate sex differences in the cortical processing of emotion.

In Study 1, ERPs were recorded from healthy women and men during a dual oddball task containing pleasant, unpleasant, and neutral stimuli to test the competing motivational and negativity bias models. N2 amplitude for women was significantly greater, reflecting more emotional orienting processes, to neutral and unpleasant relative to pleasant stimuli while N2 activation for men was increased to neutral compared to both pleasant and unpleasant stimuli, with unpleasant stimuli eliciting higher N2 amplitude than pleasant stimuli. Irrespective of sex, P3 activation was greater, indexing increased conscious appraisal and subsequent allocation of attention, to pleasant and unpleasant relative to neutral stimuli. During the dual-task condition, both women and men exhibited increased LPP amplitudes, signifying an enhanced regulatory response, to pleasant and unpleasant compared to neutral stimuli, with women displaying significantly greater LPP amplitude than men to all valences. While women rated the unpleasant stimuli as more arousing than men, no ERP evidence was found for the negativity bias. Some support, during late (P3, LPP) processing, was shown for the motivational model, however, no sex differences to emotional stimuli were demonstrated. Taken together, there was little evidence for a female negativity bias and while some support for the motivational model was demonstrated, few sex differences in emotional reactivity were shown. The findings of Study 1 were somewhat divergent from previous literature and may be explained by methodological factors, a key one of which was failure to control for menstrual phase.

As recent neuroimaging data has emerged suggesting significant differences in cortical emotional processing according to menstrual phase, Study 2 aimed to extend Study 1 by examining the impact of menstrual phase on emotional processing in women compared to men. Accordingly, ERPs were recorded from healthy women in their early follicular menstrual phase (day 1-7 (low estradiol/low progesterone)), healthy women in their midluteal menstrual phase (day 18-24 (high estradiol/high progesterone)), and from healthy men while they viewed neutral, and low- and high- arousing pleasant and unpleasant stimuli in a passive viewing task. Modulation by menstrual phase was demonstrated during early visual processing, as midluteal women exhibited significantly larger P1 amplitude at the occipital region to all visual images, relative to men, suggesting that mifluteal women have superior generally enhanced visual processing. Early follicular and midluteal women both showed greater N1 amplitudes, reflecting increased automatic preconscious processing, compared to men (although this only reached significance for the midluteal women) to the visual stimuli. No menstrual phase or sex differences were revealed during later (N2, P3, LPP) processing. In addition to statistical significance, reporting of effect sizes is important as it promotes a more scientific approach to the accumulation of knowledge by indicating the practical and clinical significance of research findings. As such, Cohen's *d* (Cohen, 1988) effect sizes were reported in Studies 2 and 3 to aid interpretation of the findings involving menstrual phase effects. Cohen's rule of thumb for interpreting effect sizes is that small effects (d=.2) represent findings of weak practical and clinical significance, medium effects (d=.5) represent findings of moderate significance, whereas large effects (d=.8) reflect findings with strong practical and clinical significance. For Study 2, the finding of enhanced P1 amplitude for midluteal women relative to men reflected a large effect size at both O1 site (d=.9) and O2 (d=.83) site whereas the greater N1 amplitude elicited by midluteal women compared to men represented a moderate to large effect size (d=.74). The results of Study 2 demonstrate that, as compared to men, women have greater early automatic visual processing, with this effect particularly strong in midluteal women at the earliest stage of visual attention processing. However, this was found to all emotional and neutral stimuli, which does not confirm predictions of the motivational model or the negativity bias hypothesis but suggests there is a generalised enhancement of visual processing in women when sex hormones are elevated.

Recent theoretical models propose that early enhanced emotional processing or reactivity to stimuli may impair later emotion regulation processes. Study 3 was designed to investigate sex differences in emotional reactivity and emotion regulation controlling for menstrual phase. To this end, ERPs were recorded from healthy early follicular women, midluteal women, and men while they completed an emotion regulation task. Midluteal women reported greater effort and distress when attempting to suppress emotional responses to unpleasant images than did men. Further, larger N2 amplitude, reflecting greater early conscious emotional orienting processes, was demonstrated during suppression for midluteal women compared to early follicular women and men. P1 and N1 amplitudes were shown to be greater in midluteal women compared to men regardless of instructional set, indicating enhanced early unconscious attentional processing. No menstrual phase or sex differences were demonstrated during late (P3, LPP) processing. Evidence from Study 3 suggest that midluteal women have difficulty down-regulating their behavioural and mid-latency (but not later) cortical responses to unpleasant stimuli during suppression, which suggests early reactivity in midluteal women may be related to difficulties with suppressing emotional responses. For Study 3, the finding of increased distress (d=.67) and effort (d=.64) reported by midluteal women relative to men during suppression reflected moderate to large effect sizes. Similarly, the larger N1 amplitude in midluteal women during suppression (d=.64) and reappraisal (d=.74) represented moderate to large effect sizes, as did the enhanced N2 component during suppression in midluteal women (d=.69). During reappraisal, the increased P1 amplitude represented a moderate to large effect size at O2 site but a large effect size at O1 site.

When considered together, the evidence from the three studies in this thesis does not provide definitive support for either the motivational model or the negativity bias hypothesis (see Appendix A). In Study 1, no evidence of the negativity bias was revealed, however, some evidence for women having greater late processing in line with the motivational model was found. Given the lack of clarity in the obtained results, we examined menstrual phase as a potential powerful and often uncontrolled influence on emotional processing in previous studies. In contrast to Study 1, when controlling for menstrual phase no support for the motivational model was found in Study 2, but some evidence for the negativity bias during late processing was found across both women and men. However, rather than find evidence of a negativity bias during early reactivity, Study 2 revealed a generalised enhancement of early visual processing for midluteal women (when sex hormone levels are high). Subsequently in Study 3 we tested whether this early visual reactivity impacted on emotion regulation, and found initial evidence of greater visual reactivity alongside reported difficulty with suppression and greater mid-latency cortical processing during suppression in midluteal women.

Overall, Study 3 extended existing emotion processing literature by examining aspects of emotion regulation in conjunction with menstrual phase. This thesis presents novel ERP evidence in Studies 2 and 3 for enhanced early visual processing in midluteal women and of deficits in suppression (with enhanced mid-latency cortical processing) in midluteal women. The finding that this suppression effect is particularly pronounced during the midluteal phase suggests that women may have heightened risk of emotional dysregulation in the later stages of their menstrual cycle. The current thesis underscores the importance of considering menstrual phase when examining sex differences in the cortical processing of visual stimuli, emotion processing, and emotion regulation processes.

CHAPTER 1: OVERVIEW OF THE THESIS

1.1. Sex Differences in Anxiety Disorders

A widely documented finding in psychiatric epidemiology is that women are significantly more likely than men to develop anxiety disorders throughout the lifespan. The National Survey of Mental Health and Wellbeing (Australian Bureau of Statistics, 2007) found that women were more likely than men to have experienced anxiety disorders both in the 12 months prior to interview (18% and 11% respectively) and in their lifetime (32% for women compared to 20.4% for men). Prevalence rates were also higher in women than men for each anxiety disorder examined, including panic disorder (5.8% vs. 4.4%), agoraphobia (7.9% vs. 4.1%), social phobia (12.8% vs. 8.4%), generalised anxiety disorder (7.3% vs. 3.6%), obsessive compulsive disorder (3.2% vs. 2.3%), and posttraumatic stress disorder (15.8% vs. 8.6%). The 2014-2015 National Health Survey (Australian Bureau of Statistics, 2015), the most recent in a series of Australia-wide health surveys collecting information on the prevalence of long-term health conditions, also demonstrates that women, relative to men, are more likely to experience anxiety (13% vs. 9.4%) disorders. Current Australian epidemiological data show highly comparable rates of anxiety and mood disorders to the United States of America with the findings of The National Comorbidity Survey showing that lifetime prevalence rates for any anxiety disorder were 30.5% for women and 19.2% for men (see Kessler et al., 1994; Kessler et al., 2005; McLean et al., 2011, for a breakdown of disorder rates in the United States of America). Further, a recent systematic review and meta-analysis of 174 large-scale mental health surveys conducted across 63 countries also demonstrated that women are twice as likely to develop an anxiety disorder than are men, with this study confirming that anxiety disorders are more prevalent in women globally (Steel et al., 2014). Overall, research demonstrates that women typically develop anxiety conditions at approximately twice the rate of men.

1.2. Proposed Mechanisms of Anxiety

Whereas research reliably demonstrates sex differences in the development and prevalence of anxiety disorders, the mechanisms underlying sex differences in these psychiatric conditions remain unclear. A range of theories have been developed with each proposing various etiological factors including evolutionary and environmental influences. For example, from an evolutionary perspective, women are seen to display heightened vigilance towards possible threats and tend to evaluate ambiguous stimuli as threatening in order to protect themselves and others, whereas from an environmental perspective increased anxiety levels in women are seen to result from sociocultural influences and gender role socialisation (McLean & Anderson, 2009; Wood & Eagly, 2002). However, while highlighting the complex processes underlying sex differences in anxiety, such evolutionary and socio-cultural theories are beyond the scope of the current project. Rather, the current thesis is focused on potential biological mechanisms such as psychophysiological reactivity and hormonal influences.

One possible biological explanation for observed sex differences in anxiety disorders is that women display greater emotional reactivity to negative emotions than men, leading to heightened sensitivity for processing unpleasant/threatening stimuli, which reflects a negativity bias (Gardener, Carr, MacGregor, & Felmingham, 2013; Li, Yuan, & Lin, 2008; Lithari et al., 2010; Stevens & Hamann, 2012). In their ERP study, Gardener et al. found greater N1 and N2 amplitudes in women compared to men which they argued reflected early emotional reactivity and preconscious processing and automatic allocation of attention to emotionally salient stimuli (Lithari et al., 2010). Early emotional reactivity has been shown to precede and influence later emotion regulation, which involves the conscious regulation of one's experience of emotionally pertinent stimuli (Gross et al., 2011). As such, an alternative explanation of the female vulnerability in anxiety disorders is that women have greater difficulty in regulating negative emotions compared with men (Cisler & Koster, 2010; Etkin, 2009; Farb et al., 2012; Gross & Jazaieri, 2014; Kring & Sloan, 2010; Price & Drevets, 2012; Waugh et al., 2012; Whittle et al., 2011).

1.3. Aim of the Thesis

The current thesis reports the series of studies which explored the potential mechanisms involved in female vulnerability for anxiety disorders, including early emotional reactivity to negative stimuli and difficulties in regulating negative emotional responses. These possible mechanisms were investigated by examining sex differences in event-related potentials to emotional stimuli, and during an emotional regulation task, with a specific focus on exploring the impact of menstrual phase on these processes.

The studies reported in this thesis were thus concerned with the perception of emotional stimuli (Studies 1 and 2) and in the regulation of emotional response to emotional stimuli (Study 3) while the influence of menstrual phase was controlled (Studies 2 and 3). Functional magnetic resonance imaging (fMRI) methodology has been used to investigate the neural networks involved during emotion processing and emotion regulation by measuring neural activation during a range of emotion processing and emotion regulation tasks (e.g., Goldin et al., 2008). While distinguishing the brain structures involved, neuroimaging emotion studies are limited as they do not permit precise assessment of the time course of processing involved during emotion processing and emotion regulation. The studies in the current thesis consequently used high temporal resolution event-related potentials (ERPs) to investigate sex differences in the neural processing of emotion: specifically in early preconscious visual processing (P1 ERP component); early preconscious attention allocation (N1 ERP component); early conscious attention allocation (N2 ERP component); and later emotion processing and emotion regulation (P3 and LPP ERP components).

CHAPTER 2: THEORETICAL FOUNDATION OF THE THESIS

2.1. Theoretical Models of Emotional Processing

Emotions can be conceptualised as basic or discrete (happiness, fear, anger, disgust, sadness, surprise, contempt), emotion systems (seeking, panic, rage, fear), behavioural states (approach/avoidance), motivational or drive states (reward, punishment, thirst, hunger, pain, craving), mood states (depression, anxiety, mania, cheerfulness, contentment, worry), and social emotions (pride, embarrassment, guilt, shame, maternal love, sexual love, infatuation, admiration, jealousy) (Adolphs, 2002). As outlined below, the studies forming the present thesis were concerned with the biphasic structure of emotion, or more specifically, emotional states that are considered to be intrinsically tied to underlying appetitive and aversive motivational systems. As defined by Izard (2010), 'emotion' consists of neural circuits (that are at least partially dedicated), response systems, and a feeling state/process that motivates and organises cognition and action. Emotions are thus characterised in terms of behavioural, physiological, and experiential responses to motivationally salient internal and external stimuli (Luck & Kappenman, 2012). Emotions can be conceived in terms of the dynamic interaction between specific stimuli and the responses they elicit in an individual (Bradley & Lang, 2000; Luck & Kappenman). Two dominant approaches have been proposed to explain the processing of emotional information, the model of motivated attention and affective states, and the negativity bias hypothesis.

2.1.1. Model of Motivated Attention and Affective States

The model of motivated attention and affective states (which will be herein referred to as the 'motivational model') was developed by Lang and colleagues (Bradley & Lang, 2000; Hamm, Schupp, & Weike, 2003; Lang, 1995; Lang, Bradley, & Cuthbert, 1990; Lang, Bradley, & Cuthbert, 1997) and is theoretically founded on the important evolutionally connection between the emotion processing system and primal approach and avoidance systems. The motivational model is concerned with the perception of emotionally distinct stimuli and posits a biphasic perspective, in that stimulus dimensions of valence and arousal elicit activation in underlying appetitive and aversive systems (Lang, et al., 1997). That is, pleasant states promote approach responses driven by the appetitive system while unpleasant states promote withdrawal responses driven by the aversive system, and arousal reflects the level of activation within either system (see Figure 1; Lang et al., 1990; Lang et al., 1992; Lang et al., 1997).

The motivational model is most applicable to research exploring primary emotional responses. Primary emotions have an inherent association with the underlying approach and withdrawal motivational systems, whereas secondary emotions surface in response to the perception and experience of a primary emotional event (Damasio, 1995; Deigh, 2014). More specifically, primary emotions are seen to be implicated in the activation of underlying drive states, or the processes involved in managing preservative (e.g., sexual and hunger drives) and protective (e.g., fear drive) functions (Bradley, 2000; Konorski, 1967; Lang & Bradley, 2010). Similar to the appetitive and aversive systems, primary reinforcements influence drive states in that successful fulfilment of drive states activates the reward receptors in the brain (e.g., mesolimbic system) while the unsuccessful fulfilment of drive states activates the punishment centres (e.g., periventricular system) (Bradley; Konorski; Lang & Bradley). Drive states are thus argued to parallel underlying motivational systems and can effectively elicit approach and withdrawal behaviours. While drive states are seen to reflect only physiological processes, the subjective feelings that are associated with particular drives and anti-drives (i.e., the feeling of contentment and satisfaction experienced following drive fulfilment) are what constitutes emotions (Bradley; Izard, 2007).

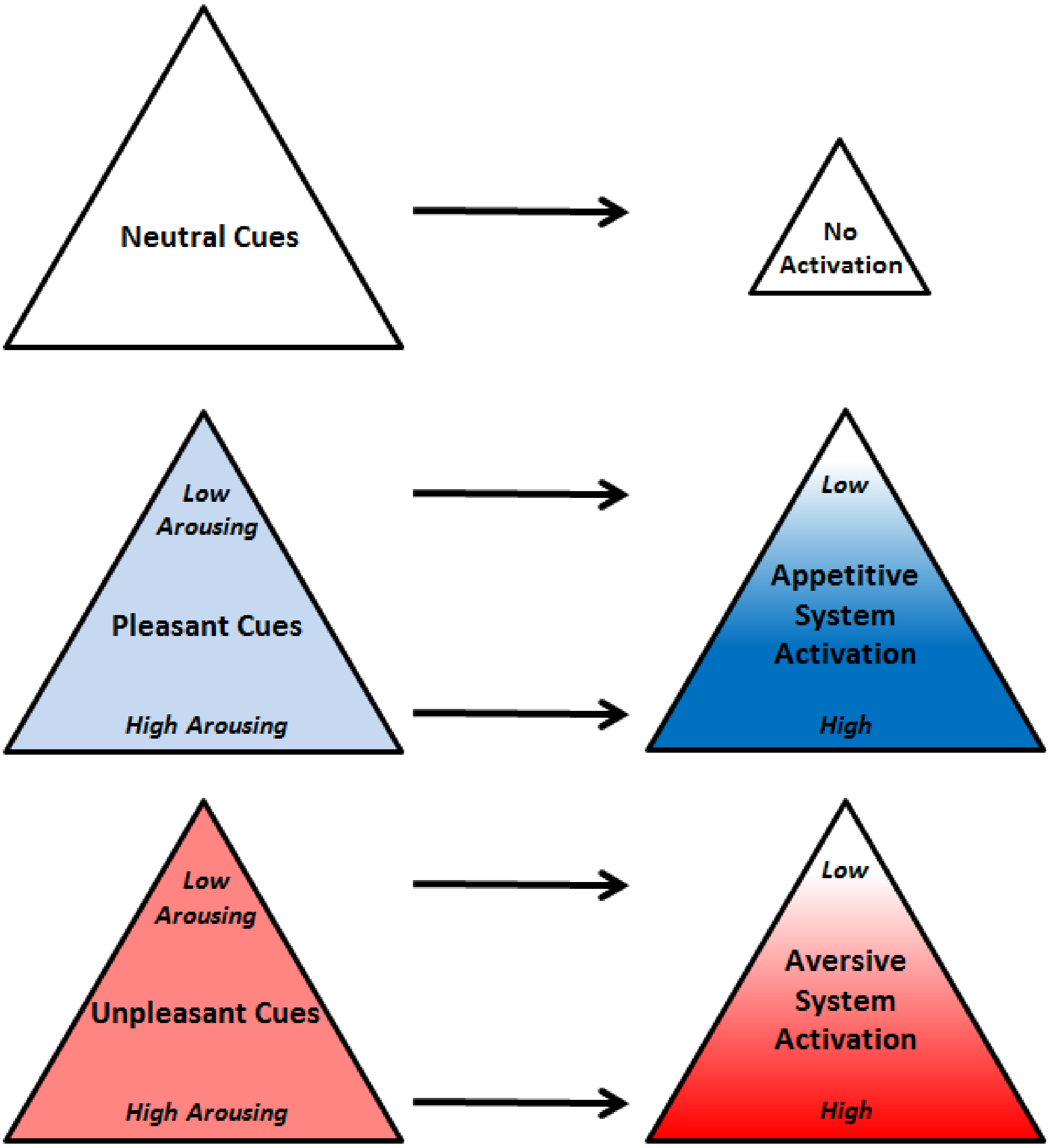

Figure 1. Visual illustration of the motivational model.

Note. The motivational model proposes that responses are larger to emotional (pleasant or unpleasant) relative to neutral stimuli, with greater reactivity to highly arousing relative to low arousing stimuli (comparable activation strength in appetitive and aversive systems). For cues: The apex of the triangle represents low arousing cues and the base of the triangle represents high arousing cues. The width of the triangle represents the level of cue arousal. For system activation: The apex of the triangle represents low system activation while the base of the triangle represents high system activation. The width of the triangle represents the level of system activation.

As theorised by Lang and colleagues (e.g., Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997; Lang & Bradley, 2010), emotions can be seen as 'action dispositions' whereby emotionally laden cues may lead to increased levels of attention and autonomic nervous system activation as an individual prepares to respond to the emotion inducing cue. These increases in attention and reactivity may be the result of either implicit or explicit emotion processing. Implicit emotion processing is automatic, unconscious, fast, and cognitively undemanding while explicit emotional processing is conscious, slow, and cognitively demanding. More specifically, implicit processing is evoked automatically by a stimulus and the stimulus is processed without monitoring and without insight and awareness of the occurring processing. In contrast, explicit processing requires conscious effort for initiation, demands some level of monitoring during processing, and is associated with some level of insight and awareness (Cohen, Moyal, Lichtenstein-Vidne, & Henik, 2016; Gyurak, Gross, & Etkin, 2011; Salmela, 2014). For example, implicit emotional processing is employed when participants are required to process a non-emotional attribute of a stimulus such as specifying whether a presented emotional face is female or male whereas explicit emotion processing is demonstrated when a participant is required to identify whether a stimulus is neutral, pleasant, or unpleasant during an emotion categorisation task (Cohen et al.; Gyurak et al.; Salmela). It is important to note that humans possess the ability to reduce or inhibit overt emotional responses following both implicit and explicit processing, even for uncontrollable covert emotional reactions through the process of emotion regulation (emotion regulation was investigated in Study 3). That is, emotions can be conceived as dispositions towards behavioural action as the body physiologically and cognitively prepares an individual for an emotional response despite the possibility that an overt response may be inhibited or not required.

In summary, the motivational model emphasises key roles of valence and arousal factors in emotion processing which map onto motivational drive states. Specifically, pleasant stimuli stimulate the appetitive system and promote approach behaviours whereas unpleasant stimuli activate the aversive system and promote withdrawal behaviours. In addition to stimuli valence, arousal is the second important dimension which influences the processing of emotional stimuli. Arousal extends from very low levels of arousal to very high levels of arousal and reflects the activation strength of the appetitive and aversive systems when processing emotional stimuli. Extreme arousal states (i.e., very low or very high) can exist within either valence (pleasant or unpleasant), and arousal level is increased at each end of the valence spectrum. The motivational model thus predicts increased reactivity to pleasant and unpleasant stimuli in comparison to neutral stimuli, with highly arousing pleasant or unpleasant stimuli evoking greater reactivity relative to low arousing stimuli (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, 1995; Lang et al., 1990; Lang, Bradley, & Cuthbert, 1992; Lang et al., 1997; Lang & Bradley, 2010).

2.1.1.1. Motivational Model: Behavioural and Physiological Evidence

The fundamental prediction of the motivational model is that pleasant and unpleasant stimuli elicit greater reactivity compared to neutral stimuli, with highly arousing pleasant or unpleasant stimuli eliciting increased reactivity relative to low arousing stimuli (Bradley et al., 2001; Lang, 1995; Lang et al., 1990; Lang et al., 1992; Lang et al., 1997; Lang & Bradley, 2010). In line with the model predictions, previous research has demonstrated that behavioural ratings of valence and arousal (i.e., pleasantness to unpleasantness; low to high arousing), heart rate, skin conductance response (SCR), startle reflex, and facial muscle activity (electromyography; EMG) are increased to pleasant and unpleasant stimuli compared with neutral stimuli, with greater reactivity to high- relative to low- arousing stimuli (Bradley, 2000; Bradley & Lang, 2000; Hamm et al., 2003; Lang et al., 1997; Lithari et al., 2010; Bernat, Patrick, Benning, & Tellegen, 2006). Further, pleasant and unpleasant stimuli relative to neutral stimuli are viewed for longer durations even when equal visual attention is directed to emotional and neutral stimuli (Bradley & Lang; Bradley et al.; Calvo & Lang, 2004; Lang & Bradley), and even under conditions where participants are instructed to focus on neutral stimuli (e.g., Nummenmaa et al., 2006). Providing additional support for the motivational model hypothesis, emotional relative to neutral stimuli require greater cortical processing (even when stimuli are unattended), have been shown to capture and hold attention, and have a greater likelihood of being recalled from memory (Buchanan & Adolphs, 2002; Schupp et al., 2007; Vuilleumier & Huang, 2009).

2.1.1.2. Motivational Model: Neuroimaging Evidence

Emotions are thought to be related to activity in brain areas that focus our attention, motivate our behaviour, and influence the significance of the stimuli and events we are exposed to. Emotion has been found to be related to a group of structures in the center of the brain called the limbic system. Research has shown that limbic structures are directly related to emotion, but non-limbic structures have also been shown to relevant to emotion (Dalgleish, 2004).

The primary structures of the limbic system include the amygdala, hypothalamus, cingulate cortex, and hippocampi (in addition to other structures). The amygdala is involved in detecting and indicating if external stimuli are important and are emotionally significant, and is particularly active when a stimulus is novel or evokes uncertainty, particularly for unpleasant emotions such as fear (Ledoux, 1995; Lindquist, Wager, Kober, Bliss-Morea, & Barrett, 2012). Research has shown enhanced amygdala activation during the perception of threat, with the amygdala accessing past memories to improve judgement of the possible threat (Breiter et al., 1996). Relatedly, the hippocampus allows memories to be stored long term and retrieves them when necessary, with such retrieval used within the amygdala to assist the evaluation of current emotional stimuli (Fischer et al., 2002; Lindquist et al., 2012).

Previous neuroimaging research has established a connection between visual processing regions (e.g., occipital cortex) and the amygdala, with amygdala reafferents thought to be involved in the early processing of stimuli in the visual cortex (de Kloet et al., 2005). A growing body of neuroimaging evidence indicates that the amygdala is primarily activated during the processing visual stimuli (relative to other sensory stimuli; Boubela et al., 2015; Phan et al., 2002) and salient stimuli (Davis & Whalen, 2001; Edminston et al., 2013; Liberzon et al., 2003). In addition, the amygdala has been found to be most activated when processing emotional stimuli

(Costafreda et al., 2008; Stevens & Hamann, 2012), although research demonstrating amygdala activation to neutral stimuli if it is salient and important to a task has also been reported (Cooney et al., 2006; Davis & Whalen, 2001; Fusar-Poli et al., 2009; Schwartz et al., 2003). In addition, the hypothalamus has been reported to be involved in reward circuits and in producing physical emotion output (Armony & Vuilleumier, 2013) whereas the cingulate cortex is seen to be important to conscious, subjective emotional awareness (Medford & Critchley, 2010).

Various other brain structures have been associated to emotion. For example, the prefrontal cortex is seen to have a critical role in the regulation of emotion and behaviour by anticipating the consequences of our actions (Davidson & Sutton, 1995) whereas the orbitofrontal cortex is a structure involved in decision making and the influence by emotion on that decision (Bechara, Damasio, & Damasio, 2000). The ventral striatum is a group of subcortical structures thought to play an important role in emotion and behaviour, including in the experience pleasure (Kringelbach & Berridge, 2016). Further, the insular cortex is thought to play a critical role in the bodily experience of emotion as it is connected to other brain structures that regulate the body's autonomic functions (heart rate, breathing) and the insula related to empathy and awareness of emotion (Gu et al., 2013; Lindquist et al., 2012).

Extensive research using fMRI methodology has demonstrated that emotional (pleasant and unpleasant) stimuli elicit greater activation compared to neutral stimuli in the visual cortical region, with enhanced activity in response to high- relative to low- arousing emotional stimuli (Aldhafeeri et al., 2012; Bernat et al. 2006; Bradley et al., 2003; Cuthbert et al. 2000; Hofstetter, Achaibou, & Vuilleumier, 2012; Lane, Chua, & Dolan, 1999; Lang et al., 1998; Lang & Bradley, 2010). Neuroimaging evidence generally supports the predictions of the motivational model, although divergent evidence which demonstrates that both valence and arousal dimensions contribute to increased activation in the visual cortical areas has also been reported (e.g., Mourão-Miranda et al., 2003).

2.1.2. Negativity Bias Hypothesis

The motivational model posits greater reactivity to emotional (pleasant and unpleasant) compared with neutral stimuli (Bradley & Lang, 2000; Hamm et al., 2003; Lang, 1995; Lang et al., 1990; Lang et al., 1997; Lang & Bradley, 2010). In contrast, a competing model of emotion processing is the negativity bias hypothesis which argues that the strength of activation between the appetitive and aversive systems varies in response to pleasant and unpleasant stimuli whereby aversive system activation is greater than appetitive system activation in response to equally stimulating appetitive and aversive information cues (see Figure 2; Cacioppo & Bernston, 1994; Cacioppo, Bernston, Norris, & Gollan, 2011; Ito, Cacioppo, & Lang, 1998; Norris, Gollan, Bernston, & Cacioppo, 2010).

Fulfilling appetitive and aversive system needs is imperative for the survival and evolution of humans. While satisfying appetitive needs such as hunger and sexual procreation is beneficial for long term survival, day-to-day survival is largely dependent on an individual’s ability to discriminate threatening from non-threatening stimuli in their environment. While negative or unpleasant events are generally encountered less frequently than positive or pleasant events, the consequences of incorrectly responding to an unpleasant event are more likely to be devastating compared to incorrectly responding to a pleasant event (Rozin & Royzman, 2001). These assumptions lead to the notion that the emotional and cognitive processing systems of humans have evolved into systems that facilitate rapid responses to unpleasant stimuli, and the observation that responses to aversive compared to equally stimulating appetitive stimuli are more rapid and pronounced, has been named the negativity bias (see Cacioppo & Berntson, 1994; Cacioppo et al., 2011; Cacioppo, Gardner, & Berntson, 1997; Ito & Cacioppo, 2005; Ito et al., 1998; Miller, 1959; Norris, et al., 2010; Rozin & Royzman).

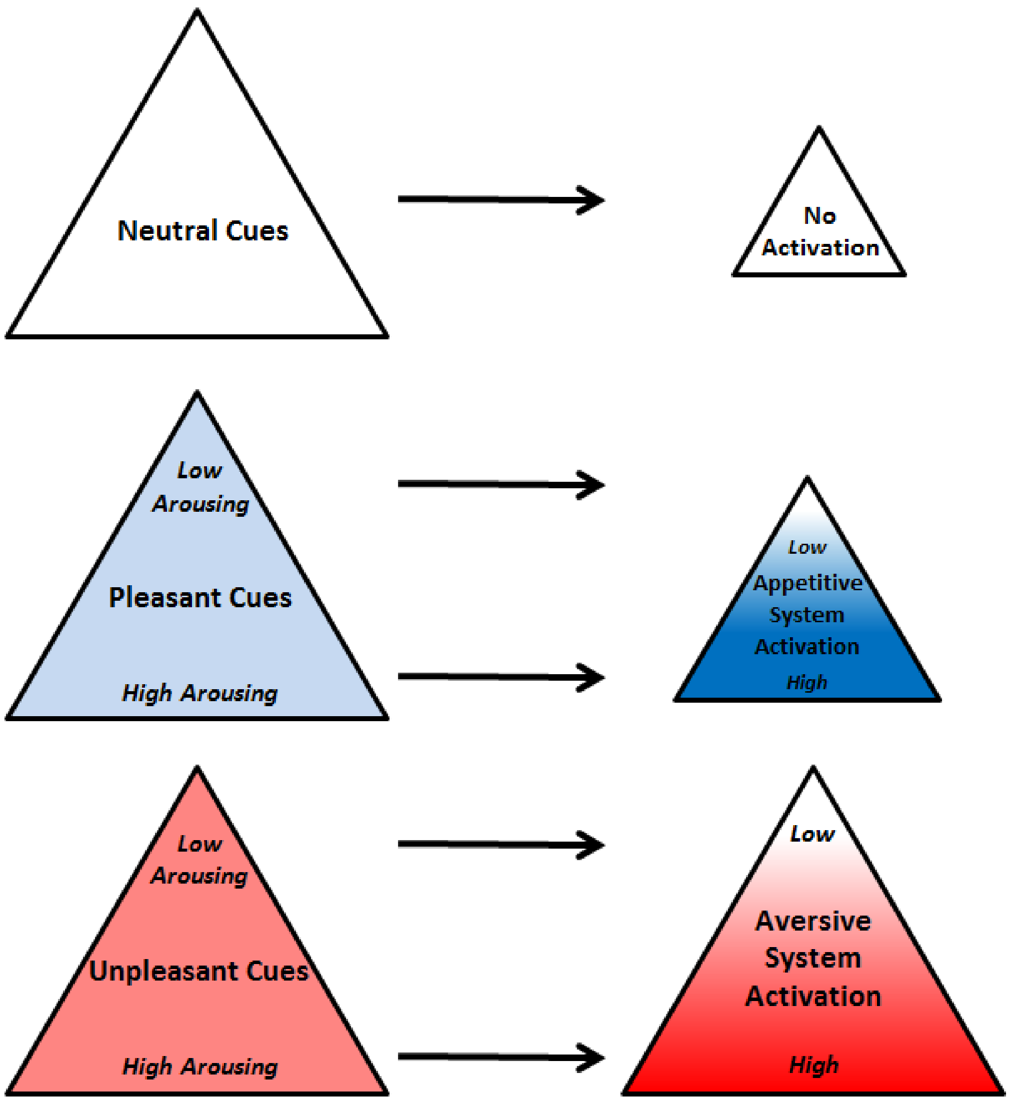

Figure 2. Visual illustration of the negativity bias hypothesis.

Note. The negativity bias hypothesis proposes that responses to unpleasant stimuli are greater relative to pleasant and neutral stimuli, with greater reactivity to highly arousing relative to low arousing stimuli (stronger activation strength in aversive system). For cues: The apex of the triangle represents low arousing cues and the base of the triangle represents high arousing cues. The width of the triangle represents the level of cue arousal. For system activation: The apex of the triangle represents low system activation while the base of the triangle represents high system activation. The width of the triangle represents the level of system activation.

One of the main principles underlying the negativity bias is the concept of ‘negative potency’ which refers to the notion that highly unpleasant events are more threatening (negative) than equally intense pleasant events are positive. That is, negative stimuli/events are typically experienced with greater emotional reactivity than pleasant events, and responses to unpleasant events are generally more varied, leading to the greater influence of unpleasant events/stimuli (Cacioppo et al., 2011; Rozin & Royzman, 2001).

In summary, the negativity bias has evolutionary implications for protective behaviours as it is seen to facilitate rapid responses to aversive stimuli to optimise survival (Cacioppo & Berntson, 1994; Cacioppo et al., 1997; LeDoux, 2012). The negativity bias hypothesis stipulates that aversive system activation is greater than appetitive system activation in response to equally strong appetitive and aversive cues. This heightened aversive system activation results in greater reactivity to, and the prioritised processing of, unpleasant relative to pleasant and neutral information, with high-arousing stimuli eliciting greater reactivity than low-arousing stimuli (Cacioppo & Berntson; Cacioppo et al., 2011; Cacioppo et al., 1997; Ito & Cacioppo, 2005; Ito et al., 1998; Miller, 1959; Norris et al., 2010; Rozin & Royzman, 2001).

2.1.2.1. Negativity Bias Hypothesis: Behavioural and Physiological Evidence

The negativity bias hypothesis predicts greater reactivity to unpleasant compared to pleasant and neutral stimuli (Bradley et al., 2001a; Cacioppo & Berntson, 1994; Ito & Cacioppo, 2005). Numerous behavioural studies indicate a negativity bias in emotion processing as reflected by faster and more accurate responses to unpleasant relative to pleasant or neutral stimuli (Mogg et al., 2000; Wentura, Rothrmund, & Bak, 2000). For example, to investigate emotional reactivity and the time taken for reactivity levels to decrease, Morriss, Taylor, Roesch, and van Reekum (2013) presented participants with pleasant, unpleasant, and neutral images followed by face stimuli, and demonstrated that the reaction time to faces following unpleasant stimuli were faster than those following pleasant or neutral stimuli. Similarly, using a word grid task, Figueiredo (2015) demonstrated that reaction time to unpleasant stimuli were faster than to pleasant or neutral stimuli.

Additionally, self-reported ratings of valence and arousal levels have been shown to be modulated by emotional stimuli. Bernat et al. (2006) collected valence and arousal ratings and assessed various physiological response systems including heart rate, SCR, startle reflex, and EMG while participants viewed pleasant, unpleasant, and neutral stimuli in a passive viewing task. Bernat et al. found that unpleasant stimuli were reported to be more unpleasant than the pleasant stimuli were considered pleasant. Similarly, Balconi, Falbo, and Conte (2012) obtained valence and arousal ratings and measured psychophysiological responses (SCR, heart rate, and EMG) while participants viewed low- and high- arousing pleasant and unpleasant stimuli in a passive viewing task and found that unpleasant stimuli were rated as more negative than pleasant and neutral stimuli with the emotional stimuli found to be more arousing than the neutral stimuli.

In addition to static emotional stimuli (i.e., emotional images), studies have demonstrated that film stimuli also show differences in valence and arousal ratings between stimuli, and evoke psychophysiological responses which may help to identify autonomic nervous system changes during emotion processing. For example, Palomba, Sarlo, Angrilli, Mini, and Stegagno (2000) examined self-report valence and arousal ratings and psychophysiological responses (SCR and heart rate) while participants viewed film clips depicting neutral or unpleasant (surgery or threat of violence) scenes. They demonstrated that unpleasant film stimuli were rated as more unpleasant and more arousing than neutral film stimuli, with no differences in valence or arousal ratings revealed between the two unpleasant film categories of surgery or violence.

In addition to valence and arousal ratings of emotional stimuli, physiological responses have been shown to vary with the emotional content of picture stimuli. For example, in studies including that of Balconi et al. (2012) described above, SCR has been shown to be larger to unpleasant relative to pleasant and neutral stimuli and greater to high- relative to low- arousing or neutral stimuli, with Balconi et al. also showing that high-arousing unpleasant stimuli elicit larger SCR than neutral and low- and high- arousing pleasant stimuli. Studies containing film stimuli have also demonstrated SCR to be greater during exposure to unpleasant threat films compared to neutral films (Palomba et al., 2000). Similarly, previous studies (e.g., Balconi et al.) have reported a consistent relationship between EMG activity and valence and arousal whereby EMG response is greater for unpleasant compared to pleasant or neutral stimuli, with high-arousing unpleasant stimuli eliciting enhanced EMG relative to neutral and low- and high- arousing pleasant stimuli.

Heart rate evidence while exposed to emotional and neutral stimuli during passive viewing tasks has also been reported to provide support for the negativity bias. In general, it has been shown that when participants view emotional images, sustained cardiac deceleration occurs, with the largest decelerations occurring during the viewing of unpleasant scenes relative to pleasant or neutral stimuli. For example, unpleasant stimuli elicited a decelerated heart rate response relative to pleasant and neutral stimuli in studies by Bernat et al. (2006) and Balconi et al. (2012). Moreover, Balconi et al. demonstrated that high-arousing stimuli produced more heart rate deceleration than low-arousing or neutral stimuli. Interestingly, heart rate evidence for the negativity bias hypothesis has also been documented in studies using film stimuli as unpleasant (threat) film have been shown to evoke an increase (as compared to decrease as most commonly reported) in heart rate compared to a neutral film (and unpleasant (surgery) films which did not differ from a neutral film) (Palomba et al., 2000). Taken together, these studies show the occurrence of distinct cardiac patterns during the viewing of unpleasant stimuli. This cardiac activity is represented by both the classic defence pattern in response to unpleasant stimuli (i.e., fight/flight response) reflected by acceleration in heart rate associated with sympathetic activation, and a more complex autonomic reaction characterised by heart rate deceleration related to sympathetic cardiac withdrawal (e.g., avoidance) or increased parasympathetic cardiac control (Balconi et al.; Bernat et al.; Palomba et al.).

The startle reflex paradigm is commonly used in emotion processing research and involves the presentation of a loud, abrupt, and unexpected sound which elicits a startle response in both humans and animals (Koch, 1999). The startle response is modulated by the brainstem and limbic network, consists of a rapid and involuntary blink, and is considered to be a reflex. Some studies (e.g., Bradley, 2000; Bradley & Lang, 2000; Lang et al., 1997) have produced evidence of increased startle reflex to pleasant stimuli, which provides support for the motivational model.However, the majority of studies show that when elicited in different emotional contexts the potentiation of the startle reflex is significantly increased in the presence of threat, fear, and pain (Bernat et al., 2006; Bianchin & Angrilli, 2012; Grillon, 2008). The startle response can subsequently be used as a measure of defensive system activation as it reflects automatic arousal/reactivity and provides a non-invasive physiological index of fear (Grillon). Supporting the negativity bias, the startle reflex has been shown to be larger in response to unpleasant relative to pleasant stimuli (Bernat et al.). Similarly, unpleasant films provoked increased probability of a startle reflex occurring as well as increased startle reflex amplitude when compared to neutral films (Palomba et al., 2000).

2.1.2.2. Negativity Bias Hypothesis: Neuroimaging Evidence

As was discussed in detail above, there is a group of cortical and subcortical brain networks which underlie emotion processing. For example, neuroimaging evidence outlining a link between visual processing brain areas (e.g., occipital region) and the amygdala has been reported, with research demonstrating that the amygdala is involved in the early processing of stimuli in the visual cortex (de Kloet et al., 2005). In addition to the literature demonstrating augmented amygdala activation during the processing of visual (Boubela et al., 2015; Phan et al., 2002) and salient stimuli (Davis & Whalen, 2001; Edminston et al., 2013; Liberzon et al., 2003), emotional stimuli has also been shown to increase activation in the amygdala (Costafreda et al., 2008; Stevens & Hamann, 2012).

Neuroimaging evidence is inconsistent as some studies show evidence in line with the motivational model whereas others provide support for the negativity bias hypothesis. Hence, neuroimaging evidence for the negativity bias has been reported as unpleasant stimuli have been shown to elicit greater neural activation compared to pleasant and neutral stimuli (e.g., Falquez et al., 2016; Gehricke et al., 2015; Keedwell et al., 2005; Siegle et al., 2002) and activation of specific brain regions associated with a negativity bias has been reported. Cunningham, Raye, and Johnson (2004) assessed brain regions involved during implicit and explicit pleasant and unpleasant evaluations and found the right inferior frontal/insular cortex to be associated with implicit and explicit valence-based evaluations of stimuli, with this area being more activated to stimuli rated as more negative than to stimuli rated as more positive.

Further, in their landmark study, Jung et al. (2006) used positron emission tomography (PET) to identify the neuroanatomical regions selectively engaged when appetitive (pleasant stimuli) and aversive (unpleasant stimuli) processing systems are simultaneously activated. Significant activation of the right frontal pole, the left middle frontal gyrus, and left inferior frontal gyrus were revealed during the negativity bias condition which involved integrated processing of both pleasant and unpleasant stimuli. Jung et al. conducted additional analyses to identify distinctively unique regions of activity and showed that only the middle frontal gyrus was activated during the negativity bias condition (integration of pleasant and unpleasant information) whereas activations in the ventromedial prefrontal, limbic, and subcortical regions were associated with the processing of univalent conditions (pleasant or unpleasant information). According to Jung et al., their findings demonstrated that participants were slower to respond and were more likely to report feeling negative (i.e., to label their subjective emotion produced by the stimuli as negative) during the negativity bias condition compared with the single valence conditions. This suggests that the processing of bivalent (both pleasant and unpleasant) stimuli requires more effort than processing of unipolar valence (pleasant or unpleasant) (Jung et al.).

Neuroimaging research allows the functional role of subcortical structures in emotion regulation and emotion regulation to be examined, however they are limited in the information they provide regarding the timing of such processes. Given that emotion processing (and negativity biases) occurs at a rapid speed and may involve both implicit and explicit processes (Cohen et al., 2016; Gyurak et al., 2011; Salmela, 2014), neuroimaging measures, in addition to behavioural and physiological measures, which have poor temporal resolution may fail to capture evidence of important but obscured covert processes involved in emotion processing. In comparison, while limited in the amount of information available to determine the functional role of cortical structures, event-related potentials (ERPs) are a high temporal resolution measure which enable examination of cortical responses across milliseconds and thus permit identification of both implicit and explicit attentional processes (Hajcak, Weinberg, MacNamara, & Foti, 2012; Luck, 2014).

CHAPTER 3: EVENT-RELATED POTENTIALS AND EMOTION PROCESSING

3.1. Event-Related Potentials

Electroencephalography (EEG) activity indexes voltage changes in electrical activity resulting from ionic current flows within the neurons of the brain (Gazzaniga, Ivry, & Magnun, 2002; Niedermeyer & da Silvia, 2004). Event-related potentials (ERPs) are the voltage fluctuations that are derived by averaging EEG activity time-locked to stimulus onset or the presence of an event which can be either internal or external to an individual. The ERP characterises the synchronistic activation of a large population of neurons from both cortical and subcortical regions (Luck, 2014). ERPs are considered to be the electrophysiological manifestation of related cognitive processes such as attention and emotion, and examination of ERP components allows the temporal course of emotional processing to be explored (Fabiani, Gratton, & Coles, 2000; Luck; Olofsson et al., 2008).

The spatial resolution of ERPs is poor as a result of the multiple neural generators involved in such activation, and due to the possible depth of cortical activation relative to the measurement of ERPs at the scalp (Fabiani et al., 2000; Friedman et al., 2001; Luck, 2012). However, the key benefits of ERPs are that they have excellent millisecond temporal resolution and provide a continuous measure of cortical processing prior to, during, and after the presentation of a stimulus and subsequent response, and are thus highly advantageous for determining which stage or stages of processing are impacted (or not impacted) by a given experimental manipulation (Fabiani et al.; Luck, 2014; Picton, Bentin, Bentin, Donchin, Hillyard, & Johnson Jr., 2000). Furthermore, key advantages of ERPs relative to behavioural, physiological, and neuroimaging measures are that ERPs enable both implicit (automatic, unconscious) and explicit (conscious) processes to be examined and permit covert measurement of processing. That is, ERPs can be used to provide a continuous measure of processing when a behavioural response is impossible or problematic (e.g., participant is physically or cognitively incapable of making a response) (Hajcak et al., 2012; Luck, 2014).

The ERP brain activity waveform encompasses a series of distinct ERP components which can be described in terms of their polarity, topography, amplitude, and latency (Fabiani et al., 2000; Friedman, Cycowicz, & Gaeta, 2001). Polarity defines the positivity or negativity of components whilst topography describes the scalp location of brain activity generally associated with each component and is described in terms of sagittal (e.g., frontal, central, parietal) and coronal (e.g., left hemisphere, midline, right hemisphere) regions. Component amplitude is measured in microvolts (μV) and is associated with processing intensity (Kolb & Whishaw, 2003) and can thus determine the effect of experimental stimuli. Latency, measured in milliseconds, is linked to the timing of cortical processing and is determined by the elapsed time between stimulus onset and amplitude peak within specified time windows (Kok, 1997).

As previously outlined, implicit emotion processing refers to automatic, unconscious, fast, and cognitively undemanding processing that does not involve awareness or insight and early ERP components (e.g., P1, N1) reflect implicit processing as these components index automatic, unconscious processing. In contrast, explicit emotion processing refers to conscious, slow, and cognitively demanding processing that does involve awareness and insight, and later ERP components (e.g., N2, P3, LPP) index conscious cortical processing and therefore reflect explicit processing (Cohen et al., 2016; Dong et al., 2011; Gyurak et al., 2011; Luck, 2000; Luck, 2014; Olofsson et al., 2008; Salmela, 2014; Schupp, Flaisch, Stockburger, & Junghöfer, 2006).

ERP components can also be described according to how they vary in response to experimental manipulations as they are differentially affected by the physical properties of a stimulus and the psychological processes invoked by the stimulus (Donchin, Kramer, & Wickens, 1986; Luck, 2014). Thus, ERP components can be seen in terms of being exogenous or endogenous. ERPs observed within the first 80ms of the EEG response are influenced by the physical properties of stimuli and are therefore modality specific, and components that are influenced by physical stimuli properties are referred to as sensory or exogenous (Fabiani et al., 2000; Luck, 2014; Picton et al., 2000). Components which reflect the activity associated with information processing functions, such as cognitive resource allocation or stimulus evaluation, are referred to as endogenous (Fabiani et al.; Luck; Picton et al.).

3.1.1. P1 Component

Whereas positive components as early as 50ms post stimulus onset are reliably demonstrated by testing in the auditory modality (Crowley & Colrain, 2004), the first identifiable peak for visually evoked potentials occurs around 100ms and has been identified as the P1 component (Luck, 2014). The P1 is a positive component that peaks around 100-130ms post-stimulus onset, and indicative of a neural generator in the primary visual cortex, the P1 typically shows maximal activation at occipital regions (Clark & Hillyard, 1996; Hillyard, Luck, & Mangun, 1994; Hopfinger & Mangun, 1998; Luck; Mangun, 1995; Mangun & Hillyard, 1991; Sass et al., 2010). However, P1 in response to emotional stimuli has also been reported at frontal sites (e.g., Carretie et al., 2007). The P1 component is seen to represent the stage of visual processing that precedes complete perceptual (e.g., sensory features) analysis and thus reflects the earliest stage of automatic attention and preconscious visual processing (Hillyard & Anllo-Vento, 1998; Luck et al., 2000; Mangun & Hillyard; Oloffson et al., 2008; Weinberg & Hajcak, 2012).

Various methodologies have been used to research the P1 component including the filter paradigm and the visuospatial cueing paradigm. This research has shown that in addition to sensory visual processing (e.g., stimuli luminance/contrast), the P1 component is modulated by top-down attentional processes and is typically increased for attended relative to unattended visual stimuli, especially in tasks requiring a rapid detection (as opposed to discrimination) of visual stimuli (Hillyard & Anllo-Vento, 1998; Heinze et al., 1990; Pourtois Grandjean, Sander, & Vuilleumier, 2004). While the P1 component has been shown to reflect processes associated with visual spatial attention, variation of the P1 component is not exclusively based on spatial attentional factors. Rather, studies have found that the P1 response is also influenced by emotion (for reviews see Carretié, 2014; Pourtois et al., 2013) as P1 has been shown to be more sensitive to the content or nature of visual stimuli compared with the actual position of a stimulus in the visual field (Di Russo et al., 2003). For instance, in a task where a neutral and an emotional face pair were flashed simultaneously in the right or left side of visual space, followed by a vertical or horizontal bar flashed to the right or left side replacing one of the emotional stimuli, P1 was larger when the bar replaced a fearful face than when it replaced a neutral face (Pourtois et al.).

Emotion effects in the primary visual cortex (triggered by a task-irrelevant stimulus) have been found to correlate with the degree of rapid spatial orienting towards the spatial location of emotional stimuli (reflected by the amplitude of the P1 elicited by a task-relevant target stimulus). This indicates a functional connection between early neural increases in primary visual cortex and the subsequent deployment of spatial attention towards emotionally salient stimuli and events (Pourtois et al., 2004, 2005a, Pourtois, Schettino, & Vuilleimier, 2012), even when the attentional demands are balanced between task conditions (Batty & Taylor, 2003; Pourtois et al., 2005b). For example, Taylor (2002) demonstrated enhanced P1 amplitudes in response to images of upright faces compared to inverted faces, and natural scenes containing animals compared to natural scenes not containing animals. Further, examining ERPs to facial expressions in healthy controls and patients with amygdala damage, Rotshtein et al. (2010) revealed decreased P1 amplitude at occipital sites in patients with amygdala damage but not in healthy controls. This lead to the conclusion that the amygdala significantly influences early automatic visual processing, as reflected by the occipital P1. Taken together, these results provide evidence that P1 amplitude is sensitive to the saliency of stimuli and to the emotional content of stimuli.

P1 has been associated with emotion categorisation processing (Pizzagalli et al., 2002) as P1 amplitude has been shown to be larger for unpleasant emotional faces than for pleasant emotional faces (Ito et al., 1998; Smith et al., 2003). Similarly, studies using the dot probe paradigm have found P1 amplitude to be larger following fearful relative to happy faces (Pourtois et al., 2004) and after angry relative to happy faces (Santesso et al., 2008).

Santesso et al. interpreted their findings to be suggestive of increased sensory gating for emotionally cued stimuli in the visual cortex and to be consistent with theories on hyper-vigilance towards threat. Likewise, Brosch, Pourtois, Sander, and Vuilleumier (2011) and Brown et al. (2010) found larger P1 amplitude to congruently primed targets (e.g., threat) compared with incongruently primed targets in a spatial cueing paradigm. Brown et al. also reported that both evolutionary relevant (e.g., snakes) and evolutionary irrelevant (e.g., guns) stimuli elicited greater probe P1 amplitudes in congruently primed trials compared to incongruently primed trials which indicated that all types of threatening stimuli capture attention relative to non-threatening stimuli. Further, enhanced P1 amplitude has also been reported for neutral stimuli where the location is cued by a preceding emotional stimulus, relative to a neutral cue (Pourtois et al., 2004, 2005b, 2012). Emotion-word Stroop tasks have also revealed enhanced occipital P1 to threat stimuli during both rapid/‘subliminal’ and supraliminal presentation rates (Li et al., 2007), providing evidence of preferential processing of threat and again demonstrating that the P1 component provides an index of unconscious visual processing.

In addition to visuospatial cueing, filter, categorisation, Stroop, and dot probe paradigms, passive viewing tasks have been used to investigate the P1 component. Hot, Saito, Mandai, Kobayashi, and Sequeira (2006) required participants to complete a passive viewing task containing pleasant, unpleasant, and neutral images and found P1 amplitude to the emotional (pleasant and unpleasant) stimuli to be greater than for the neutral stimuli. Smith et al. (2003) presented participants with neutral pictures with occasional pleasant and unpleasant images interspersed in a passive viewing task and demonstrated that unpleasant stimuli evoked larger P1 amplitude than pleasant stimuli. Similarly, Feng et al. (2014) recorded ERPs while participants passively viewed pleasant and unpleasant low- and high- arousing images and demonstrated that P1 amplitude was larger to unpleasant relative to pleasant stimuli. Rellecke, Sommer, and Schacht (2012) used a passive viewing task containing unpleasant, pleasant, and neutral stimuli and required participants to either explicitly identify the emotional expression of a face stimulus or implicitly process emotional expression. They found that unpleasant expressions (anger) elicited a larger P1 than pleasant or neutral expressions during both the implicit and explicit conditions. Conversely, no emotion modulation of the P1 was found in the study by Foti et al. (2009) where participants viewed pleasant, unpleasant, and neutral stimuli in a passive viewing task, possibly because the temporospatial principle component technique used to analyse ERPs did not fully differentiated the P1 and N1 components.

Despite P1 modulation reported in a range of studies, little support for the motivational model has been reported with the exception of Hot et al. (2006) who showed P1 to be greater to pleasant and unpleasant relative to neutral stimuli during a passive viewing task. Rather, consistent with the negativity bias hypothesis, greater P1 amplitude in response to unpleasant relative to pleasant and/or neutral stimuli is most commonly reported in studies using a diverse range of task including categorisation, spatial cueing, dot-probe, Stroop, and passive viewing tasks (Brosch et al., 2011; Brown et al., 2010; Feng et al., 2014; Li et al,. 2007; Pourtois et al., 2004, 2005a, 2012;

Rellecke et al., 2012; Smith et al., 2003). It should be noted however, that while support for the negativity bias hypothesis is reliably reported, the majority of these studies did not examine P1 response to pleasant stimuli. Thus these findings are not a direct a test of whether emotional valence or emotional arousal is preferentially associated with attentional bias and early visual processing reflected by the P1 component.

In summary, there is much evidence that the P1 component is sensitive to varying levels of attention, to the saliency of stimuli, and is seen to provide an index of the earliest stage of preconscious visual processing. Enhanced P1 to emotional stimuli has been found using a wide range of paradigms including spatial cueing, dot-probe, and passive viewing tasks. While some P1 evidence in line with the motivational model has been reported (e.g,. Hot et al., 2006), the majority of studies reporti greater P1 to unpleasant relative to pleasant and neutral stimuli which indicates that unpleasant stimuli receive more attention than pleasant (and neutral) stimuli during early preconscious visual processing (Brosch et al., 2011; Brown et al., 2010; Feng et al., 2014; Li et al,. 2007; Pourtois et al., 2004, 2005a, 2012; Rellecke et al., 2012; Smith et al., 2003).

3.1.2. N1 Component

During visual tasks the P1 component is normally followed by a negative peaking component known as the N1, generally occurring between 100 and 240ms post stimulus onset (Fabiani et al., 2000; Luck, 2014). Although N1 is widely distributed over the entire scalp, it is typically maximal frontally which is suggestive of distinct frontal network correlates (Luck et al., 2000; Luck; Schupp et al., 2006). The N1 is argued to reflect a frontal attentional mechanism that regulates sensory processing in visual cortices (Pérez-Edgar & Fox, 2003) and thus indexes early preconscious attention allocation and visual processing (Dong et al., 2011; Hinojosa et al., 2015; Luck et al.; Luck).

Multiple research paradigms, including filtering and visuospatial cuing paradigms, have been used to understand how experimental manipulations influence the N1 component. Natale, Marzi, Girelli, Pavone, and Pollmann (2006) investigated the cortical correlates of exogenous and endogenous spatial attention on target location by displaying stimuli in blocks of same-location and randomised-location trials respectively. Demonstrating that N1 indexes automatic orienting of attention, larger N1 amplitude was shown for random-location relative to same-location presentations. Zani and Proverbio (2012) conjointly examined space- and object- based attention mechanisms by presenting complex, familiar shapes of artefacts and animals. These were intermixed with distracter stimuli, in different tasks requiring the selection of a relevant target-category within a relevant spatial location (while ignoring the other shape categories within this location) and, overall, all the categories at an irrelevant location. N1 was shown to be greater at attended compared to unattended locations which is consistent with a range of previous studies (e.g., Clark & Hillyard, 1996; Zani & Proverbio, 2006). Object-features were also shown to increase N1 amplitude as this component was larger for both the congruent shape-relevance conditions compared to those elicited in the mixed condition in the right hemisphere. On the other hand, N1 was larger in the left hemisphere for relevant compared to irrelevant shapes. Zani and Proverbio (2012) argue these findings suggest that visual selective attention is able to modulate cortical processing of object features independent of spatial processing. This conclusion is strongly supported by Fu, Zinni, Squire, Kumar, Caggiano, and Parasuraman (2008) who reported a significant interaction for N1 amplitude between voluntary visuospatial attention and perceptual load, whereby N1 amplitude was larger (attentional enhancement) for the high- relative to low- perceptual load stimuli.

N1 modulation and its association with visual attention has been reported in the selection of competing stimulus attributes. For example, in the pioneering study by Zani and Proverbio (1997), ERPs to attentionally relevant and irrelevant stimuli were compared and N1 was shown to be enhanced for relevant compared with irrelevant spatial frequencies. Similarly, in a study involving the selection of one of two transparent superimposed surfaces, Khoe, Mitchell, Reynolds, and Hillyard (2005) demonstrated modulation of the N1 component for relevant compared with irrelevant surface. Within an attended space location, the N1 elicited by a cued surface was shown to be larger than the N1 elicited by an uncued surface, and this ERP cueing effect was present even when the two surfaces were identical in colour. Thus providing evidence that automatic selective attention and orientation results in preferential selection of the cued surface during early visual processing.

The mean amplitude difference for N1 between detected and undetected targets provides a measure of attentional orientation towards low-level sensory features such as luminance (Luck et al., 2000). For example, in an early study by Wijers, Lange, Mulder, and Mulder (1997) the effects of visual spatial attention and letter target detection for stimuli presented against a (nonisoluminant) dark background or isoluminant grey background was investigated. Increased N1 amplitude for the isoluminant condition demonstrated that selective attention operates at the level of early perceptual processing. N1 modulation by luminance was also reported by Papera and Richards (2016) who investigated visual processing during a visual search task and found larger N1 amplitude to be associated with target detection, with this result demonstrating selective attention and orientation towards the target stimuli.

Taken together, this body of research demonstrates that spatial and object attention serve as early selection mechanisms that influence the selection of other perceptual features, such as colour or motion, for further processing (Hinjosa et al., 2015). N1 amplitude is largest for perceptual features in attended (compared with unattended) locations and on attended (compared with unattended) objects. N1 and selective attention research thus provides evidence that perceptual features are only selected for further perceptual processing if they are in attended locations or focused on attended objects (Anllo-Vento & Hillyard, 1996; Luck et al., 2000; Martinez et al., 2006). The N1 therefore reflects perceptual discrimination processes, selective attention, and preconscious attention allocation (Luck, 2000; 2014; Schoomberg, Schone, Gruber, & Quirin, 2016).

As for the P1 component, the N1 does not exclusively reflect visual spatial attention processing as it has been found to be modulated by emotion. Enhanced shifts in attention orientation from target stimuli towards competing emotional compared to neutral distractor stimuli, have consistently been demonstrated (for reviews see Carretié, 2014; Pourtois et al., 2013) with greater N1 amplitude to emotional relative to neutral distractors most commonly reported. It should be noted, however, that while all studies examining automatic attention have presented unpleasant distractors, less than half have included pleasant distractors, with this bias preventing valence effects from being distinguished from arousal effects (Carretié).

In the study by Hinojosa et al. (2015), where participants completed a digit-categorisation task in which task-irrelevant positive, negative, and neutral words were flanked with numbers, positive distractor words were shown to evoke increased N1 amplitudes relative to negative and neutral task-irrelevant words. Doallo, Holguín, and Cadaveira (2006) recorded ERPs to task-irrelevant unpleasant and neutral images displayed briefly at peripheral locations while participants performed a central perceptual discrimination task. They found greater N1 for the unpleasant relative to the neutral stimuli. Similarly, De Cesarei, Codispoti, and Schupp (2009) presented pleasant, unpleasant, and neutral images at peripheral locations while participants passively viewed the images or completed a distractor task. Emotional stimuli were shown to modulate ERP responses only when participants were passively viewing the images indicating that perceptual processing resources are required for identification and emotional processing of peripherally presented stimuli. Taken together, these studies demonstrate that N1 reflects selective attention and orientation towards task-irrelevant emotional relative to neutral stimuli.

Early emotional reactivity is regarded as an automatic preconscious process within emotion processing paradigms (Hajcak et al., 2012) and ERP research has associated early emotional reactivity with earlier, negative ERP components (e.g., N1) which in turn is argued to reflect preconscious, automatic, processing of emotional stimuli (Näätänen, 1992; Lithari et al., 2010; Luck, 2014). When considering the discrimination, orienting, and selective attention functions reflected by the N1 previously noted, emotional biases in emotion processing reflects a distinct neural system for “emotional attention”. This is argued to aid the selection of stimuli for awareness and further processing, with this selection based on the emotional saliency of stimuli rather than sensory or spatial characteristics (Lang et al., 1997; Pourtois et al., 2012; Vuilleumier, 2005; Vuilleumier & Huang, 2009).

The N1 component has been shown to be sensitive to the emotional content of visual stimuli (Carretie et al., 2004; Carretie et al., 2007; Foti et al., 2009; Keil et al., 2001; Weinberg & Hajcak, 2010, 2011). For example, ERPs were recorded by Carretie et al. (2007) while participants completed a categorisation task containing pleasant, unpleasant, and neutral images, and N1 was shown to be larger to emotional (pleasant and unpleasant) relative to neutral stimuli. Likewise, Weinberg and Hajcak (2010), who recorded ERPs while participants passively viewed images presented in pleasant, unpleasant, and neutral blocks, demonstrated that N1 was enhanced to emotional (pleasant and unpleasant) compared with neutral stimuli. Modulation of emotional response has also been reported in studies which have used facial expressions as their task stimuli, such as Foti, Hajcak, and Dien (2009) who recorded ERPs while participants viewed positive (e.g., smiling faces), negative (e.g., sad faces), and neutral (e.g., neutral faces) stimuli in a passive viewing task. Specifically, this task revealed increased N1 amplitude to both positive and negative facial expressions relative to neutral expressions. In contrast, using an orthogonal passive viewing task containing low- and high- arousing pleasant and unpleasant images, N1 magnitude was greater to unpleasant relative to pleasant stimuli (Lithari et al., 2010). Similarly, Gardener et al. (2013) instructed participants to either increase, decrease, or maintain their emotional responses while passively viewing unpleasant images, and showed greater N1 to the stimuli which was argued to reflect early emotional reactivity.

N1 amplitude has been shown to support both the motivational model and the negativity bias hypothesis across a range of studies and experimental paradigms. In line with the motivational model, emotion categorisation tasks (e.g., Carretie et al., 2007) and passive viewing tasks containing neutral and positively and negatively valanced stimuli (e.g., Carretie et al., 2004; Foti et al., 2009; Weinberg & Hajcak, 2010) have consistently demonstrated N1 to be enhanced to pleasant and unpleasant as compared to neutral stimuli. Further, studies using stimuli depicting positive, negative, and neutral facial expressions as stimuli have also shown N1 amplitude to be greater to emotional relative to neutral stimuli (Foti et al., 2009), with no evidence of a negativity bias despite the unpleasant stimuli being rated by participants as more arousing than the pleasant stimuli. However, the modulation of emotional stimuli reflected by the N1 component is inconsistent as passive viewing tasks, comprising low- and high- arousing pleasant and unpleasant stimuli, and emotion regulation tasks have revealed evidence of a negativity bias in N1 processing (e.g., Gardener et al., 2010; Lithari et al., 2010). Further, although not consistently demonstrated (e.g., Codispoti et al., 2007; Olofsson & Polich, 2007), the N1 has been shown in earlier studies to be resistant to habituation specifically for highly arousing unpleasant stimuli, relative to pleasant and neutral stimuli (Carretie et al., 2003).

In summary, the N1 component has been associated with the automatic orientation of processing resources and/or the modulation of perceptual cortical mechanisms and is seen to index preconscious allocation of attention (Di Russo et al., 2005; Hinojosa et al., 2015; Luck, 2014). Additionally, the N1 has been identified as a marker of early emotional reactivity and is seen to reflect the automatic and preconscious processing of emotional stimuli (Näätänen, 1992; Lithari et al., 2010) with the magnitude of N1 shown to be increased by emotional (pleasant and/or unpleasant) as compared to neutral stimuli, with some studies reporting support for the motivational model and others finding support for the negativity bias hypothesis (Carretie et al., 2007; Foti et al., 2009; Keil et al., 2001; Lithari et al.; Weinberg & Hajcak, 2010, 2011).

3.1.3. N2 Component

The N2 component reflecting early negativity between 100 and 350ms post stimulus onset shows maximal activation at central or frontal regions and is argued to index early conscious attention allocation (Fabiani et al., 2000; Luck et al., 2000). The visual N2 component is found in a variety of different experimental paradigms and its topography varies as a function of experimental task type; with a fronto-central N2 component evoked during flanker or noise-compatibility tasks (e.g., Seifert, Naumann, Hewig, Hagemann, & Bartussek, 2006), an N2 evoked at both frontal and parietal regions during some go-nogo tasks (e.g., Heil, Osman, Wiegelmann, Rolke, & Henninghausen, 2000; Lavric, Pizzagalli, & Forstmeier, 2004), and a frontal and central N2 component produced in emotion processing tasks (e.g., Li et al., 2008; Lithari et al., 2010).

The amplitude of the N2 component increases in response to expectancy violations resulting from the presentation of low probability stimuli (Heil, Osman, Wiegelmann, Rolke, & Henninghausen, 2000). The N2 component has also been proposed to reflect inhibition and conflict monitoring processes (Lavric et al., 2004). Further, the N2 is also seen as an early ERP marker of conscious stimulus classification or stimuli discrimination processes (i.e., stimulus identification) for visually presented stimuli (Dien, Spencer, & Donchin, 2004; Di Russo et al., 2006).

With respect to emotion processing, as the N2 component is seen to index early conscious attention allocation (Fabiani et al., 2000; Luck et al., 2000), the N2 has been associated with the early conscious processing of emotional stimuli and thus increased selective attention to emotional relative to neutral stimuli (Foti et al., 2009; Lithari et al., 2010; Näätänen, 1992). Both pleasant and unpleasant stimuli have been shown to modulate the amplitude of the N2 component in passive and active tasks, even when emotional stimuli are only briefly presented (e.g., Keil et al., 2002; Schupp et al., 2004). For example, Li et al. (2008) examined ERPs during a categorisation task which contained highly unpleasant, moderately unpleasant, and neutral images, and revealed N2 to be larger to the highly unpleasant stimuli as compared to the moderately unpleasant and neutral stimuli, with moderately unpleasant stimuli also shown to elicit a larger N2 than neutral stimuli. In contrast, other studies have reported increased N2 to pleasant stimuli rather than to unpleasant or neutral stimuli. Feng, Wang, Wang, Gu, and Luo (2012a) examined the processing of erotic-pleasant, non-erotic pleasant, unpleasant, and neutral stimuli using ERPs and showed N2 amplitude to be greater to the pleasant (erotic) relative to unpleasant and neutral stimuli, with no differences found between the other three image categories indicating that the erotic stimuli selectively captured participants attention.

A range of studies have employed an orthogonal design of valence (pleasant/unpleasant) and arousal (low/high) to investigate the processing of emotional stimuli. Rozenkrants and Polich (2008) recorded ERPs while participants completed an oddball task with this orthogonal design and demonstrated that high-arousing relative to low-arousing stimuli elicited greater N2 amplitude, while no valence effects were found. Similar arousal findings were reported by Feng et al. (2014) who examined emotional picture processing using a passive viewing task with the same orthogonal design to show that at the high-arousal level unpleasant stimuli elicited increased N2 amplitude relative to pleasant stimuli, whereas at the low-arousal level pleasant stimuli produced greater N2 amplitude as compared to unpleasant stimuli. Contrasting findings were reported by Feng et al. (2012b) who investigated the time course of the implicit processing of emotional stimuli to reveal that N2 amplitude was increased for low-arousing negative stimuli relative to high-arousing unpleasant stimuli whereas N2 amplitudes elicited by low- and high-arousing pleasant were not significantly different. Further, N2 amplitudes were greater for low-arousing unpleasant stimuli relative to low-arousing pleasant stimuli, whereas no significant differences in N2 amplitude were observed for high-arousing pleasant and unpleasant stimuli. While N2 arousal effects have been variously demonstrated, other studies have only reported valence effects. For instance, using a passive viewing task with an orthogonal design, Lithari et al. (2010) demonstrated that N2 amplitude was greater to unpleasant relative to pleasant stimuli, with no differences in arousal levels for the pleasant and unpleasant stimuli.

Research has shown the magnitude of the N2 component to be sensitive to valence differences in unpleasant stimuli. In addition, the studies by Yuan et al. (2007), Yuan, Yang, Meng, Yu, and Li (2008), and Meng, Yuan, and Li (2009) presented highly unpleasant, moderately unpleasant, and neutral stimuli while participants completed a standard/deviation categorisation task (irrespective of the emotional valence of the deviants). A task block involving highly pleasant, moderately pleasant, and neutral stimuli was also examined by Yuan et al. Results in each of the studies demonstrated enhanced N2 in response to highly unpleasant relative to moderately unpleasant and neutral stimuli. Moreover, moderately unpleasant stimuli elicited significantly greater N2 amplitudes than neutral stimuli. These findings suggest that unpleasant emotions of diverse strength, as evoked by unpleasant stimuli of varying valences, are clearly different in their impact on early conscious visual processing. Further, Yuan et al. found no differences in N2 amplitude to highly pleasant, moderately pleasant, and neutral stimuli which, they argued, indicates that the sensitivity of humans to valence differences is specific to unpleasant stimuli.

When considering how previous N2 findings map to the predictions of the motivational model and negativity bias hypothesis, previous research overall indicates that the N2 component is most sensitive to highly arousing emotional stimuli relative to low arousing and neutral stimuli (e.g., Feng et al., 2014; Rozenkrants & Polich, 2008). Considering the valence dimension, some evidence for the motivational model has been reported, such as the study by

Schupp et al. (2007) in which a passive viewing task containing highly arousing pleasant, highly arousing unpleasant, and low arousing control images was used to reveal increased N2 amplitude to the pleasant and unpleasant relative to the control stimuli. However, other research has found increased N2 specifically to pleasant relative to unpleasant stimuli (e.g., Feng et al., 2012a) which does not provide clear support for the motivational model. N2 findings upporting the negativity bias have also been found, as N2 amplitude has most consistently been found for both low- and high-arousing unpleasant relative to pleasant and neutral stimulih (e.g., Feng et al., 2012b; Feng et al., 2014; Li et al., 2008; Lithari et al., 2010).

In summary, the N2 component represents the degree of early conscious attention allocation that is needed for processing of stimuli discrimination and classification, is recognised as an indicator of early conscious emotion processing. The N2 has been shown to be sensitive to emotional (pleasant and/or unpleasant) relative to neutral stimuli in line with the motivational model (Fabiani et al., 2000; Folstein & Van Petten, 2008; Li et al., 2008; Lithari et al., 2010; Luck et al., 2000; Oloffson et al., 2008), however such evidence is tempered by other studies which demonstrate support for the negativity bias hypothesis (e.g., Li et al., 2008; Lithari et al., 2010).

3.1.4. P3 Component

The P3 component is typically observed between 250 and 500ms post stimulus onset with the scalp distribution of P3 distinguishable between a frontally maximal P3a component reflecting orienting of attention, and of relevance to the current thesis, a P3b component maximal at centro-parietal and parietal sites. The P3b is said to reflect conscious attention depending on the experimental task (Conroy & Polich, 2007; Luck, 2014; Polich, 2007). Whilst not fully elucidated, there is evidence of a circuit pathway between frontal and temporal/parietal brain areas (Polich & Criado, 2006; Polich). A temporal-parietal neural generator appears logical given that P3 appears to be elicited when attentional resource activations promote working memory and other processes in temporal-parietal areas (Polich). Furthermore, EEG research utilising source modelling techniques, along with research using alternative brain imaging methods (e.g., fMRI, MEG), intracranial recordings, and brain injury patients, has also indicated that the P3 component originates from activation in the parietal and temporal lobes of the cerebral cortex. There is also some evidence that activation in certain limbic structures, such as the anterior cingulate cortex, may contribute to the P3 component (Polich & Criado).

The P3 has been recognised as an endogenous electrophysiological measure of a number of neural processes, including attentional resource allocation, attention to emotionally salient or motivationally significant stimuli, and modulation of emotional responses prior to later emotion regulation processes (Luck, 2014; Moser et al., 2009; Olofsson et al., 2008). The P3 component has been observed in a variety of emotion processing paradigms employing a range of tasks including selective attention, emotional memory, emotional oddball, emotional dual-task, emotion processing, and emotion regulation tasks (e.g., Kok, 2001; Luck; Polich, 2012). Research has demonstrated an inverse relationship between P3 amplitude and subjective probability whereby P3 amplitude is enhanced in response to stimuli that are task-relevant as a result of experimental instructions, personal relevance, or emotional/motivational significance (Luck). Further, similar to the function of the N2 component, the amplitude of the P3 component increases in response to expectancy violations resulting from the presentation of low probability stimuli (Heil, Osman, Wiegelmann, Rolke, & Henninghausen, 2000; Luck).

In their recent review of ERPs and emotion processing Hajcak et al. (2010) emphasised the P3 as a primary marker of emotion processing although mixed findings have been reported. For example, Delplanque et al. (2006) recorded ERPs while participants categorised emotional images as being either pleasant, unpleasant, or neutral target pictures embedded in a string of standard stimuli and found enhanced P3a to unpleasant relative to pleasant and neutral images. However, P3b was shown to be sensitive to the arousal level of stimuli, with increased amplitudes for pleasant and unpleasant relative to neutral stimuli. Conroy and Polich (2007) required participants to respond to pleasant, unpleasant, and neutral images matched on arousal level and demonstrated reduced P3 amplitude to unpleasant relative to pleasant and neutral stimuli over frontal areas. Investigating ERP components sensitive to emotional relative to neutral stimuli using temporospatial principal components analysis, Foti et al. (2009) analysed ERPs following passive viewing of pleasant, unpleasant, and neutral stimuli. They demonstrated greater P3 reactivity to emotional (pleasant and unpleasant) compared with neutral stimuli.

Passive viewing tasks presenting participants with neutral and low- and high- arousing pleasant and unpleasant stimuli have also been used to show enhanced P3 to emotional relative to neutral stimuli, with greater P3 found for high arousing in comparison with low arousing and neutral stimuli (Balconi et al., 2012). In contrast, measuring ERPs while participants responded to low- and high- arousing pleasant and unpleasant stimuli during an oddball task, Rozenkrants and Polich (2008) demonstrated that, while high- relative to low- arousing stimuli elicited increased P3 amplitude, modulation of the P3 component according to valence was not observed. Hence, while some support for the negativity bias hypothesis has been supported, it appears that the majority of emotion ERP literature has overall revealed that the P3 component is greater in response to emotional relative to neutral stimuli (with enhanced P3 magnitudes to high- relative to low-arousing stimuli) and P3 effects have been observed during passive (e.g., viewing) and active (e.g., emotion discrimination, oddball) tasks. The P3 thus reflects stimulus saliency, with emotional (pleasant and unpleasant) relative to neutral stimuli commanding attention and thereby assisting later processing (i.e., “motivated attention”, Bradley et al., 2003; Lang et al., 1997; Sabatinelli et al., 2005). That is, emotional stimuli elicit a sustained increase in attention as a result of their salience and receive increased processing resources as reflected by enhanced P3 amplitudes.

Like the N2, the P3 component has been shown to vary according to the intensity of unpleasant stimuli. In studies where participants were exposed to highly unpleasant, moderately unpleasant, and neutral stimuli during completion of a standard/deviation categorisation task (independent of deviant valence), P3 has been found to be greater in response to highly unpleasant relative to moderately unpleasant and neutral stimuli, with moderately unpleasant stimuli also found to evoke larger P3 amplitudes than neutral stimuli (Meng et al., 2009; Yuan et al., 2007, 2008). These findings suggest that humans are sensitive to valence differences in unpleasant stimuli with such differences impacting conscious attention to emotionally salient or motivationally significant stimuli.

The P3 component has been shown to be involved in the later, conscious appraisal of emotion and in the modulation of emotional responses before later emotion regulation occurs. Specifically, Moser et al. (2009) measured ERPs during anticipation, and processing, of unpleasant stimuli during an emotion regulation task which required participants to either decrease or increase their emotional response to the stimuli. Moser et al. demonstrated that ERP modulation in response to the unpleasant stimuli commenced around 300ms post stimulus-onset (i.e., within the window that the P3 component is generally observed) with this ERP modulation occurring just prior to regulation effects indexed by the LPP component. They interpreted the activity in the P3 time window as representative of appraisal of emotion and this occurs prior to emotion regulation.

P3 amplitude has also been shown to be consistently modulated in response to emotional stimuli under specific emotion regulatory instructions. For example, to investigate whether regulation of emotions impacts cognitive resources available to complete a subsequent task, Devenley and Pizzaigalli (2008) recorded ERPs while participants were instructed to increase, decreased or maintain their emotional responses to unpleasant stimuli before then evaluating whether a word was neutral or negative. Reflecting depleted cognitive resources following the increase instruction, P3 amplitude was shown to be smallest for words presented after participants increased their emotional responses to the unpleasant stimuli.

A range of experimental P3 providing support for the motivational model have been reported. Such evidence includes the findings of Delplanque et al. (2006) who showed increased P3b amplitudes to pleasant and unpleasant compared with neutral stimuli during an oddball task, and Balconi et al. (2012) and Foti et al. (2009) who both demonstrated greater P3 magnitude to emotional (pleasant and unpleasant) relative to neutral stimuli during a passive viewing task. However, research in line with the negativity bias model has also been reported with a number of ERP studies revealing greater P3 amplitude to unpleasant compared to pleasant and neutral stimuli (e.g., Delplanque et al., 2005, 2006; Ito et al., 1998). Further, this P3 negativity bias finding is observed when the arousal dimension of emotional stimuli is the same, as was demonstrated by Conroy and Polich (2007) who required participants to respond to pleasant, unpleasant, and neutral images matched on arousal level and found larger P3 amplitude to unpleasant relative to pleasant and neutral stimuli. Similarly, Cano, Class, and Polich (2009) showed P3 amplitude to be sensitive to stimulus valence in the absence of stimulus arousal differences. However, they showed larger P3 amplitude to pleasant relative to unpleasant and neutral stimuli which does not provide support for either the motivational model or negativity bias hypothesis.

In summary, the determining factors of P3 amplitude are task-relevance, the motivational significance or emotional salience of stimuli, arousal level, and the influence of these factors on attentional resource allocation (Olofsson et al., 2008). The P3 component is seen as an index of emotion processing (Hajcak et al., 2010) with P3 in emotion research reflecting the attentional resources demanded by motivationally or emotionally relevant stimuli and to index cortical activation during emotion processing and prior to emotion regulation processes (Luck, 2014; Moser et al., 2009; Olofsson et al., 2008). To date P3 findings in the emotion processing literature is unclear, as P3 evidence in line with both the motivational model (Balconi et al., 2012; Foti et al., 2009) and negativity bias hypothesis (e.g., Cano, Class, & Polich, 2009; Ito et al., 1998) has been reported.

3.1.5. Late Positive Potential

The Late Positive Potential (LPP) elicited between 400 and 800ms post stimulus onset reflects a broadly distributed positivity (Friedman & Johnson, 2000) that is maximal at central and parietal sites (Krug et al., 2000). In terms of the neural source of the LPP, the characteristic scalp distribution of the LPP suggests that it may reflect neural activity generated in the posterior parietal cortex (Keil, Bradley, Hauk, Rockstroh, Elbert, & Lang, 2002; Sabatinelli, Lang, Keil, & Bradley, 2007; Rugg & Curran, 2007). The LPP has been researched within a number of paradigms including attention and both short and long term memory paradigms, and has been found to be particularly relevant for emotion processing (Olofsson et al., 2008). As the LPP is evoked when perceptual demands are high, the LPP is assumed to provide an index of further processing that is beyond the capacity reflected by the P3 component (Rugg & Curran, 2007). Discussed further below, the LPP is thought to index the intrinsic motivational significance of emotional stimuli and provide an indication of the timing and level at which evaluation of a stimulus influences further stimuli processing and response appraisal (Cacioppo, Crites, & Gardner, 1996; Leite et al., 2012; Purves et al., 2008).

Previous emotional ERP research has consistently found LPP to be highly sensitive towards emotionally salient stimuli (pleasant and unpleasant) compared to neutral stimuli (e.g., Balconi et al., 2012; Cuthbert et al., 2000; Flaisch, Junghöfer, Bradley, Schupp, & Lang, 2008; Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; Hajcak, Dunning, & Foti, 2007; Hajcak & Olvet, 2008; Hajcak et al., 2010; Hilgard, Weinberg, Hajcak, & Barthlow, 2014; Hot et al., 2006; MacNamara & Hajcak, 2009, 2010; Olofsson et al., 2008; Pastor, Bradley, Low, Versace, Molto, & Lang, 2008; Sand & Derntl, 2011; Schupp et al., 2000; 2003, 2006; 2012; Weinberg & Hajcak, 2010; Wiens, Sand, Norberg, & Andersson, 2011). Such findings provide evidence that attention is more deeply engaged by motivationally relevant stimuli (i.e., stimuli that activate the appetitive and aversive systems) as compared to neutral information (e.g., Amrhein et al., 2004; Cuthbert et al., 2000; Keil et al., 2002; Schupp et al., 2003, 2004, 2004, 2012). However, a number of studies have demonstrated that unpleasant stimuli elicit larger LPPs than pleasant or neutral stimuli (e.g., Cano et al., 2009; Carretié, Hinojosa, Martín-Loeches, Mercardo, & Tapia, 2004; Carretié, Mercardo, Tapia, & Hinojosa, 2001; Cuthbert et al., 2000; Delplanque et al., 2004, 2005, 2006; Feng et al., 2014; Foti et al., 2009; Hajcak & Olvet, 2008; Huang & Luo, 2006; Ito et al., 1998; Kaestner & Polich, 2011; Smith et al., 2003; Stewart et al., 2010; Yuan et al., 2007), even when the unpleasant and pleasant stimuli are equally arousing (e.g., Ito et al.).

In addition to stimuli valence, LPP to emotional relative to neutral pictures has been shown to be larger for more intense stimuli (i.e., stimuli with higher arousal ratings and eliciting the greatest SCR; Cuthbert et al., 2000), and is thus greater for highly arousing pleasant (e.g., erotica) and unpleasant (e.g., threat) stimuli (Schupp, Junghöfer et al., 2004; Schupp, Ohman et al., 2004; Cuthbert et al., 2004). Additionally, enhanced LPP for emotional compared to neutral stimuli does not show habituation over repeated presentations of stimuli (Codispoti, Ferrari, & Bradley, 2006, 2007; Olofsson & Polich, 2007; Syrjanan & Wiens, 2013). Further, in the studies by Yuan et al. (2007), Yuan et al. (2008), and Meng et al. (2009) where participants were required to view highly unpleasant, moderately unpleasant, and neutral stimuli while competing a standard/deviation categorisation task, LPP amplitude was found to be greater to the highly unpleasant relative to moderately unpleasant and neutral stimuli, with moderately unpleasant stimuli also eliciting larger LPP amplitudes than neutral stimuli. These findings highlight the sensitivity of the brain to different valence levels in emotionally unpleasant stimuli during stimuli evaluation processes which are reflected by the LPP.

As indicated above, the LPP response to emotionally salient stimuli (high arousing pleasant or unpleasant relative to neutral stimuli) has been consistently reported across a range of paradigms. For example, Hilgard et al. (2014) investigated whether task paradigm and stimuli content influenced the occurrence of a negativity bias by presenting participants with pleasant affiliative, pleasant thrilling, unpleasant threatening, and neutral images in the context of oddball, blocked, and random viewing paradigms. They demonstrated that pleasant and unpleasant stimuli produced a larger LPP than did neutral stimuli across all task paradigms. They also found a negativity bias in the oddball paradigm when thrilling rather than affiliative stimuli were used. Overall, current evidence suggests that emotional modulation of the LPP is a robust and stable effect and that the LPP indexes motivational significance and emotional salience, and thus the degree to which attention is allocated to emotional stimuli (Bradley, 2009; Olofsson et al., 2008).

Further research has demonstrated that the LPP is consistently modulated by emotion regulation instruction whereby LPP activation has been shown to be higher when emotional reactivity is increased and lower when one's emotional response is decreased. For example, Moser et al. (2006) examined the LPP during an emotion regulation task in which participants were instructed to maintain, decrease (suppress), or increase their emotional responses to unpleasant images and found reduced LPP during the decrease instruction. Hajcak and Nieuwenhuis (2006) replicated these findings by recording ERPs during an emotion regulation task which involved participants attending to, or reappraising, unpleasant images to demonstrate reduced LPP following reappraisal. Similarly, Moser et al. (2009) and Gardener et al. (2013) measured ERPs during an emotion regulation task that required participants to maintain, decrease (reappraise), or increase their emotional response to unpleasant images. Moser et al. and Gardener et al. found increased LPP amplitude following the increase emotional response instruction, with Moser et al. also finding reduced LPP following the decrease instruction. Hence, the LPP provides a robust and objective electrophysiological marker of later, conscious, response-related emotion regulation (Dennis & Hajcak, 2009;

Gardener et al., 2013; Moser et al., 2006; Moser et al., 2009; Moser et al., 2010; Oloffson et al. 2008).

Experimental paradigms demonstrating LPP evidence for the motivational model have been reported, with previous ERP studies demonstrating that the LPP is greater to emotional (both pleasant and unpleasant) relative to neutral stimuli (e.g., Balconi et al., 2012; Cuthbert et al., 2000; Flaisch et al., 2008; Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; Hajcak et al., 2007, 2010; Hajcak & Olvet, 2008; Hilgard et al., 2014; Hot et al., 2006; MacNamara & Hajcak, 2009, 2010; Olofsson et al., 2008; Pastor et al., 2008; Sand & Derntl, 2011; Schupp et al., 2000; 2003, 2006; 2012; Weinberg & Hajcak, 2010; Wiens et al., 2011). Such findings provide evidence that attention is more deeply engaged by motivationally relevant stimuli (i.e., stimuli that activate the appetitive and aversive systems) as compared to neutral information (e.g., Amrhein et al., 2004; Cuthbert et al., 2000; Keil et al., 2002; Schupp et al., 2003, 2004, 2004, 2012). However other studies report enhanced LPP to unpleasant relative to pleasant and neutral stimuli (e.g., Cano et al., 2009; Carretié et al., 2001, 2004; Cuthbert et al., 2000; Delplanque et al., 2004, 2005, 2006; Feng et al., 2014; Foti et al., 2009; Hajcak & Olvet, 2008; Huang & Luo, 2006; Ito et al., 1998; Kaestner & Polich, 2011; Meng et al., 2009; Smith et al., 2003; Stewart et al., 2010; Yuan et al., 2007, 2008), even when the unpleasant and pleasant stimuli are equally arousing (e.g., Ito et al.).

A positivity bias where pleasant stimuli can elicit comparable or even more pronounced LPP responses compared with unpleasant stimuli has also been reported (e.g., Brown, van Steenbergen, Band, de Rover, & Nieuwenhuis, 2012), with a recent meta-analysis revealing a modest attentional bias for pleasant compared with neutral stimuli in both early and late processing (Pool, Brosch, Delplanque, & Sander, 2016). Further, other studies have found no valence differences in LPP response (e.g., Glaser, Mendrek, Germain, Lakis, & Lavoie, 2012; Rozenkrants & Polich, 2008; Weinberg et al., 2012). Research such as the study by Hilgard et al. (2014) noted above suggests that task paradigm and the semantic content of emotional stimuli influences whether the negativity bias effect is observed in the LPP.

In summary, the LPP has been observed in emotion processing and emotion regulation tasks. LPP amplitude has been associated with the emotional intensity of stimuli which indicates that LPP modulation is influenced by the motivational importance and/or emotional salience of stimuli (Bradley, 2009; Friedman & Johnson, 2000; Krug et al., 2000; Moser et al., 2009; Oloffson et al., 2008). The LPP has consistently been found to be a non-habituating regulative response which is sensitive to highly arousing emotional (pleasant or unpleasant) relative to neutral stimuli, and is consequently seen to reflect a robust index of emotion processing and emotion regulation (Dennis & Hajcak, 2009; Moser et al., 2006, 2009, 2010). However studies showing motivational model support are tempered by other studies which have reported evidence in line with the negativity bias hypothesis (Foti et al., 2009; Hajcak & Olvet, 2008; Yuan et al., 2007, 2008).

CHAPTER 4: SEX DIFFERENCES IN EMOTION PROCESSING

4.1. Sex Differences in Emotion Processing

Due to women developing anxiety at twice the rate than men (Kessler et al., 2005; McLean et al., 2011), research has focused on examining possible sex differences in threat processing and neural function. This research has been conducted using a range of methodologies such as psychophysiology measures to assess arousal responses to threat, ERPs to examine cortical processing, and neuroimaging to identify relevant anatomical regions. As women develop more anxiety disorders than men, it has been proposed that women may display a greater negativity bias to processing threat, revealed by enhanced threat processing specifically to unpleasant stimuli (Gardener et al., 2013; Li et al., 2008; Lithari et al., 2010; Stevens & Hamann, 2012). In contrast, others propose that women may have greater emotional processing in general, which may be related to socialisation and sociocultural influences (McLean & Anderson, 2009; Wood & Eagly, 2002), and which would be reflected by women showing greater processing of both pleasant and unpleasant stimuli relative to men (Bradley et al., 2001b; Cuthbert et al., 2000; Schupp et al., 2000).

4.1.1. Sex Differences in Motivational Model: Behavioural and Physiological Evidence

Increased behavioural and physiological reactivity in women to emotional relative to neutral stimuli has been demonstrated. A film paradigm was used by Quevedo, Smith, Donzella, Schunk, and Gunnar (2010) to investigate valence and arousal ratings and the startle reflex while participants viewed pleasant, unpleasant, and neutral film clips. Women were shown to rate the pleasant and unpleasant films as being more positive and negative respectively than men, although both women and men rated the pleasant and unpleasant films as more arousing compared to the neutral films. Further, women, when compared to men, were shown to be more likely to exhibit a startle reflex, and when they did, their startle reflex amplitude was greater than that of men. Greater emotional reactivity in women has also been reported by Chentsova-Dutton and Tsai (2007) who examined sex differences in SCR response while participants relived previous emotional events and experiences. Women were found to have greater SCR activity when reliving both pleasant and unpleasant experiences than men. However, while this study shows that women were more reactive than men, it should be noted that the motivational model effect cannot be fully supported as a neutral ‘condition’ was not possible given the nature of the task.

4.1.2. Sex Differences in Motivational Model: Neuroimaging Evidence

Previous neuroimaging research show that sex differences in brain activation are complex and region-specific, such that the direction of sex differences varies in functionally distinct brain regions (Andreano, Dickerson, & Barrett, 2014; Wager, Phan, Liberzon, & Taylor, 2003). Further, reports of sex differences in regional brain activation during emotion processing vary as a function of the experimental task employed (e.g., emotional perception; emotional reactivity; mood induction; see reviews by Bradley & Lang, 2010; Stevens & Hamann, 2012; Whittle et al., 2011). In addition, it should be noted that the possible greater emotionality effect in women (i.e., pleasant and unpleasant greater than neutral stimuli) has not been fully explored in the majority of previous neuroimaging studies which have typically involved experimental tasks which did not contain pleasant and/or neutral stimuli.

Sabatinelli, Flaisch, Bradley, Fitzsimmons, and Lang (2004) measured brain activation while participants viewed a range of pleasant, unpleasant, and neutral images. They found that both men and women exhibited increased activation in the visual cortex in response to emotional (pleasant and unpleasant) relative to neutral stimuli. This finding was consistent with the notion that the motivational relevance of visual stimuli directs attention and enhances elaborative perceptual processing (Bradley & Lang, 2010). However, as shown by Sabatinelli et al. and in later studies, interestingly, men seem to have a greater response to pleasant stimuli that portray erotica. Specifically, men have been shown to rate pleasant stimuli, particularly erotic stimuli (e.g., opposite sex nudes and erotic couple images), as significantly more pleasant and arousing and respond with significantly larger skin conductance responses and self-reported arousal while viewing erotic stimuli compared to women (e.g., Bianchin & Angrilli, 2012; Bradley & Lang, 2007; Bradley et al., 2001b, 2001b; Chivers et al., 2010; Rupp & Wallen, 2008; Sass et al., 2010). Men have also been found to have greater extrastriate, visual cortex, amygdala, and hypothalamus activity than do women when viewing erotica. Such findings provide neurophysiological evidence of increased appetitive activation in men relative to women, particularly in response to sexual stimuli (Hamann, Herman, Nolan, & Wallen, 2004; Karama et al., 2002; Sabatinelli et al., 2004).

Wager et al. (2003) conducted a quantitative meta-analysis on 65 neuroimaging studies of emotion processing focussing on the effects of emotional valence (pleasant/unpleasant/neutral and approach/withdrawal) and on sex differences in regional brain activation. They demonstrated that in response to emotional relative to neutral stimuli, women tend to activate midline limbic structures, including the subcallosal anterior cingulate, thalamus, midbrain, and cerebellum, whereas men typically activate posterior sensory and association cortex, left inferior frontal cortex, and dorsal striatum more than women. These findings may reflect sex differences whereby women may give greater attention to the feeling state elicited by emotional stimuli (Orozco & Ehlers, 1998; Wager et al.) or may show more overt responses to emotion (e.g., perhaps for social reasons; Kring & Gordon, 1998). On the other hand, men may direct greater attention to sensory features of emotional stimuli and process them in terms of implications for required action.

In summary, previous behavioural, physiological, and neurophysiological findings regarding sex differences in emotion processing are inconsistent and do not provide definitive evidence that women are more emotionally reactive relative to men. Reflecting a negativity bias, women tend to be more reactive to emotional stimuli, particularly stimuli that are unpleasant, threatening, or traumatic whereas men are more appetitively activated and preferentially process pleasant (particularly erotic) stimuli (Bradley & Lang, 2010; Stevens & Hamann, 2012; Whittle et al., 2011). However, null findings have also been reported whereby no differences between men and women in emotional response systems including self-reports, psychophysiology, and neural activation have been found (Fugate, Gouzoules, & Barrett, 2009; Kelly, Tyrka, Anderson, Price, & Carpenter, 2008; see McRae et al., 2008; Wager et al., 2003). While a comprehensive study of sex differences in appetitive and aversive system processing has been conducted using behavioural measures (e.g., ratings of valence and arousal demonstrating stronger aversive and appetitive tendencies for women and men respectively), physiological measures (e.g., SCR, heart rate, startle reflex, EMG) and neurophysiological measures (e.g., fMRI), less experimental attention has been directed towards the investigation of sex differences in the electrophysiological activation involved in emotion processing.

4.1.3. Sex Differences in Motivational Model: Electrophysiological Evidence

With respect to the motivational model, women and men are both expected to be more responsive to emotional compared to neutral stimuli (regardless of valence), with women demonstrating greater reactivity relative to men (Bradley et al., 2001b). Support for the motivational model has been reported in many ERP studies. ERP component amplitudes, in response to highly arousing pleasant and unpleasant stimuli compared to low arousing or neutral stimuli, have been reliably established for both men and women, with high arousing stimuli shown to elicit larger ERP amplitudes in women relatively to men (Olofsson et al., 2008). Sex differences in cortical activity to emotion-relevant infrequent compared to neutral infrequent stimuli have been demonstrated by Orozco and Ehlers (1998). They showed that infrequently presented emotional faces (pleasant and unpleasant) evoked larger P450 amplitudes than neutral stimuli in women but not in men during a facial discrimination task. Thus providing evidence for the motivational model in women. Pfabigan, Lamplmayr-Kragl, Pintzinger, Sailer, and Tran (2014) provided support for the motivational model in women using a modified dot probe task containing angry, happy, and neutral facial stimuli. In this study women were shown to have larger P1 to emotional (particularly happy stimuli) relative to neutral stimuli following both standard (i.e., mean amplitude) and difference wave analyses. Pfabigan et al. interpreted these results as evidence that women orient their attention to emotional stimuli more so than men which concurs with reports of greater neural activity during early visual processing in women compared to men. Similarly, Proverbio, Brignone, Matarazzo, Zotto, and Zani (2006) recorded ERPs while participants viewed pleasant, unpleasant, and neutral facial expressions and showed P1 amplitude to be much larger in women than in men, regardless of facial expression, indicating that women are more responsive in general compared to men. In another study, Campanella et al. (2004) demonstrated that while men and women have exhibited faster N2 reactivity to fearful faces, women also displayed faster N2 reactivity to happy faces.

Further electrophysiological evidence of the motivational model in women was reported by Groen, Wijers, Tucha, and Althaus (2013) who examined the temporal dynamics of emotion processing by requesting participants view pleasant, unpleasant, and neutral images containing humans or scenes in a passive viewing task. N2 amplitude was found to be higher to both pleasant and unpleasant relative to neutral stimuli in women, with no differences for men revealed. Mixed model support was also found by Bianchin and Angrilli (2012) who investigated sex differences in emotional responses while participants viewed pleasant, unpleasant, and neutral images. Providing support for the motivational model, greater LPP amplitude to pleasant and unpleasant relative to neutral stimuli was found at the parietal region, however, this effect was shown for both women and men indicating no difference in emotional responsivity across the sexes. However, when a significant interaction involving sex, valence, and electrode site was explored, LPP amplitude to neutral relative to pleasant stimuli was found for men while women were shown to have greater LPP to unpleasant relative to pleasant stimuli consistent with the negativity bias. However, such findings are unconvincing as the effects were found at a nonstandard electrode site (F7; frontal left hemisphere electrode) and the findings are in the opposite direction as to what is commonly reported (i.e., higher amplitude to neutral relative to emotional stimuli).

Cuthbert et al. (2000) utilised a passive viewing task containing pleasant, unpleasant, and neutral stimuli and found that for women pleasant and unpleasant stimuli (particularly high-arousing stimuli content such as violence or erotica) evoked greater magnitude within a slow positive waveform (e.g., LPP) than neutral stimuli. This finding was seen to be indicative of selective processing of emotional stimuli and of activation of motivational systems in the brain. While demonstrating greater reactivity to emotional relative to neutral stimuli in women, and in accordance with the motivational model, the Cuthbert et al. study is limited as only a female sample was used.

4.1.4. Sex Differences in Negativity Bias: Behavioural and Physiological Evidence

Previous research has demonstrated modulation of emotion processing as a function of sex. As discussed above, the valence and arousal qualities of emotion-inducing stimuli activate the brains underlying appetitive and aversive systems (Lang et al., 1997). Correlational research has demonstrated that women have greater aversive system activation while men have greater appetitive system activation (Bradley et al., 2001b). Furthermore, women show greater behavioural and psychophysiological reactivity to unpleasant/threatening stimuli than men.

In their seminal study, Bradley et al. (2001b) investigated the emotional reactions (arousal and valence ratings, heart rate, skin conductance, facial EMG measures) of women and men while they viewed pleasant, unpleasant, and neutral images in a passive viewing task. Bradley et al. demonstrated that women rated the unpleasant images as being more unpleasant and more arousing than men. In a similar study by Bianchin and Angrilli (2012), participants viewed pleasant, unpleasant, and neutral stimuli in a passive viewing task while their arousal and valence ratings, heart rate, EMG, skin conductance, and startle reflex responses were collected. Relative to men, women rated all slides as less pleasant and reported increased arousal in the unpleasant condition. A negativity bias in stimuli ratings was also reported by Syrjanen and Wiens (2013) who investigated sex differences in responsiveness to emotional distractors to find that women rated unpleasant stimuli as more arousing than pleasant images, and more unpleasant than rated by men. Further, while no sex differences in startle reflex was found by Armbruster, Strobel, Kirschbaum, and Brocke (2014), women were shown to rate unpleasant stimuli as significantly more unpleasant and arousing then men which is consistent with a negativity bias explanation in women. The finding of increased unpleasantness and arousal in adult samples has also been reported in child samples. For example, Sharp, Van Goozen, and Goodyer (2006) collected ratings of valence and arousal from children who viewed pleasant and unpleasant images varying in arousal level (low, medium, high) to show that girls rated the unpleasant stimuli as being more unpleasant than boys.

In addition to higher levels of perceived unpleasantness and arousal, women have also been shown to have faster reaction times and higher accuracy to emotive (predominantly unpleasant) stimuli relative to men. Further, women have been shown to have greater speed and accuracy associated with the detection and recognition of emotional stimuli and to memorise emotional events better than men (Collignon, Girard, Gosselin, Saint-Amour, Lepore, & Lassonde, 2010; Hoffmann, Kessler, Eppel, Rukavina, & Traue, 2010; Kret & De Gelder, 2012; Montagne, Kessels, Frigerio, de Haan, & Perrett, 2005; Ros & Latorre, 2010; Whittle et al., 2011).

SCR has also been argued to demonstrate increased reactivity to unpleasant stimuli in women compared to men. For example, Bradley et al. (2001b) found that women exhibited larger SCR amplitude to unpleasant compared to pleasant and neutral stimuli whilst men responded with similar SCR when viewing pleasant and unpleasant stimuli relative to neutral stimuli. Bradley et al. also reported facial EMG data which showed women elicited increased EMG activity when viewing unpleasant stimuli compared to men, with no difference found for neutral or pleasant stimuli for either women or men. Consistent with other physiological evidence of increased reactivity to unpleasant stimuli in women, the Bradley et al. study also demonstrated that women elicited higher levels of fear bradycardia (i.e., immobility and sustained cardiac deceleration) when viewing unpleasant stimuli (regardless of specific content) compared with pleasant and neutral stimuli.

As earlier noted, startle reflex amplitude is larger in response to unpleasant relative to pleasant stimuli (e.g., Bernat et al., 2006). While some studies including that of Bradley et al. (2001b) have not found sex differences in startle reflex, previous research have most commonly demonstrated that startle reflex amplitude is greater in women as compared to men in response to unpleasant stimuli (e.g., Bianchin & Angrilli, 2012; Grillon, 2008). Further, Gard, Germans, and Kring (2007) examined startle responses during and following the presentation of pleasant, unpleasant, and neutral stimuli to measure whether women and men differ in their patterns of immediate response to emotional stimuli and in their patterns of recovery from these responses. While women and men both displayed higher startle reflex amplitude during the presentation of unpleasant relative to neutral images, during the recovery period this potentiation was sustained in women only, indicating that women continued to have aversive system activation after the offset of the unpleasant stimuli.

In addition to valence, contextual factors have been shown to modulate the magnitude of the startle response. For example, Grillon (2008) measured the startle response while participants were exposed to predictable aversive shocks signaled by a cue, unpredictable shocks, or no shocks with startle stimuli delivered regularly throughout the task conditions. While no sex differences in fear-potentiated startle to a threat cue was found, the sustained increase in startle in the predictable and unpredictable conditions was larger in women compared to men, which was interpreted by Grillon as reflecting increased negative contextual processing in women relative to men.

4.1.5. Sex Differences in Negativity Bias: Neuroimaging Evidence

Evidence of a female negativity bias has been reported in various neuroimaging studies. Some studies have demonstrated sex differences in brain activation in the absence of sex differences in behavioural measures. For example, Kempton et al. (2009) measured brain activation while participants completed a facial affect recognition task (fearful, neutral) to reveal an effect of sex on brain activation during the recognition of fearful faces, despite no sex differences in task performance. Specifically, women demonstrated greater activity than men in the left amygdala and right temporal pole with no other brain regions found to be more activated in men compared to women.

Other studies have reported sex differences in both behavioural performance and brain activation. Han et al. (2008a) presented participants with images showing a person in either a safe or a potentially dangerous situation and asked them to detect threat signals and to evaluate the degree of threat. They showed that women responded faster than men during the detection of threat cues in visual scenes depicting dangerous situations while men evidenced stronger posterior parietal activation (and increased connectivity between this region and the medial prefrontal cortex) than women. Although not directly relevant to the current study as depressed participants were examined, Gollan et al. (2015) more recently examined the functional localisation of negativity bias by presenting pleasant, unpleasant, and neutral images to depressed and healthy women with low- and high-expression of negativity bias. Participants with high negativity bias expression rated the unpleasant and pleasant images as more unpleasant and pleasant respectively compared to participants with low- negativity bias expression.

Additionally, high negativity bias participants with depression were also shown to have greater brain activation in the left inferior frontal gyrus than depressed participants with low negativity bias.

Inconsistent evidence has been reported in studies researching specific sex differences in amygdala activation. Andreano et al. (2014) presented participants with images varying on levels of valence (pleasant, unpleasant, neutral) and arousal (low, medium, high) and found that women and men showed similar activation in response to novel unpleasant stimuli, however, women displayed a sustained amygdala response to familiar unpleasant stimuli compared to men. Further, while some studies reveal larger amygdala response in women when unpleasant stimuli are passively viewed (e.g., Domes et al., 2010), greater amygdala activation in men compared to women in response to stimuli depicting animal and human attacks relative to disgust-inducing and neutral stimuli has also been reported (Schienle et al., 2005). In contrast, other studies have failed to find sex differences in amygdala activation during viewing of emotional stimuli (e.g., Aleman & Swart, 2008; Wrase et al., 2003).

In their recent quantitative meta-analysis, Stevens and Hamann (2012) revealed significant sex differences to emotional (pleasant or unpleasant) relative to neutral stimuli emotion. Women were shown to be more activated to unpleasant stimuli while men were more responsive to pleasant stimuli, with these effects most evident in the amygdala which is known to be a major region for emotion processing. Specifically, for unpleasant stimuli women, relative to men, showed greater left amygdala activation in addition to other regions including the left thalamus, hypothalamus, mammillary bodies, left caudate, and medial prefrontal cortex. In contrast, for pleasant stimuli, men as compared to women, displayed increased left amygdala activity, with increased activation in other areas such as the bilateral inferior frontal gyrus and right fusiform gyrus. As discussed by Stevens and Hamann, these findings reveal that the amygdala shows valence-dependent sex differences in activation to emotional stimuli. The finding of increased left amygdala activation to unpleasant stimuli for women concurs with research which shows women to have greater reactivity to unpleasant stimuli (e.g., Whittle et al., 2011) and increased rates of anxiety as compared to men (e.g., McLean et al., 2011).

On the other hand, the greater left amygdala activation in men to pleasant stimuli indicates that greater amygdala activity previously reported for specific types of positive stimuli (e.g., erotica; Bianchin & Angrilli, 2012) may also broaden to pleasant stimuli more generally. While overall it appears that women display an enhanced negativity bias compared to men, previously reported sex differences to emotional stimuli in behavioural, physiological, and neuroimaging responses are varied and inconsistent. Similarly, the extent to which sex differences are reflected in electrophysiological data remains a largely unresolved issue.

4.1.6. Sex Differences in Negativity Bias: Electrophysiological Evidence

While some evidence of sex differences in emotion processing, consistent with the motivational model has been found, more recent ERP studies have consistently reported data which demonstrates a negativity bias in women. For example, Groen et al. (2013) revealed that women displayed greater P1 amplitude over the right hemisphere for unpleasant relative to neutral stimuli, and larger LPP amplitudes to unpleasant relative to neutral stimuli, with no valence differences demonstrated for men. In a study investigating sex differences in emotion processing, Lithari et al. (2010) recorded ERPs while participants viewed low- and high- arousing pleasant and unpleasant images in a passive viewing task. This study revealed greater N1 and N2 amplitudes to unpleasant images for women compared to men, and Lithari et al. argue this greater early emotional reactivity to unpleasant stimuli provides support for the negativity bias. Similarly, when emotional reactivity was examined by Gardener et al. (2013), significantly enhanced N1 and N2 amplitudes to unpleasant stimuli in women compared with men was demonstrated.

Further evidence for a negativity bias in women was provided by Han et al. (2008b) who presented participants with neutral and unpleasant (pain) stimuli to show that while men and women both displayed increased P3 amplitude to the unpleasant compared to neutral stimuli, this effect was significantly more pronounced in women. It should be noted however, that the Gardener et al. and Han et al. studies only compared unpleasant and neutral stimuli, and thus, the potential greater emotionality effect in women, reflected by greater reactivity to emotional (pleasant and unpleasant) relative to neutral stimuli cannot be ruled out.

A number of studies have demonstrated that women are more sensitive to unpleasant stimuli of lower valence saliency than men. As outlined previously, Li et al. (2008) required participants to complete an oddball task containing highly unpleasant, moderately unpleasant, and neutral stimuli which differed in valence level but were similar in arousal level. Li et al. demonstrated that while both men and women exhibited greater N2 and P3 amplitudes to highly unpleasant images compared to neutral images, only women displayed significantly enhanced N2 and P3 amplitudes towards moderately unpleasant stimuli as compared to neutral stimuli. Similarly, Yuan, Luo, Yan, Meng, Yu, and Li (2009) recorded ERPs while participants completed two standard/deviation distinction tasks which contained either highly unpleasant, moderately unpleasant, and neutral stimuli, or highly pleasant, moderately pleasant, and neutral stimuli. No valence or sex differences were found during the pleasant stimuli condition. In contrast, both women and men showed greater N2 and P3 amplitudes to highly unpleasant relative to moderately unpleasant and neutral stimuli. However women, but not men, demonstrated enhanced N2 and P3 amplitudes to the moderately unpleasant as compared to neutral stimuli. More recently, Luo et al. (2014) examined sex differences in emotion processing while participants viewed highly unpleasant, moderately unpleasant, and neutral stimuli. LPP at parietal sites revealed a sex effect, in that for women highly unpleasant stimuli elicited greater LPP amplitudes than the moderately unpleasant stimuli, which in turn elicited larger LPP than the neutral condition, whereas for men highly unpleasant stimuli elicited a larger LPP than moderately unpleasant and neutral stimuli with no difference between the moderately unpleasant and neutral stimuli. Taken together, these studies demonstrate that, while both sexes are sensitive to highly unpleasant stimuli, women are sensitive to unpleasant stimuli of lesser salience and thus appear to have lowered thresholds for responding to unpleasant stimuli as compared to men (Li et al.; Luo et al.; Yuan et al.).

Enhanced responsivity in women to unpleasant stimuli also extends to the anticipation of unpleasant stimuli with subsequent effects on encoding of emotional information into long-term memory. Galli, Wolpe, and Otten (2011) examined sex differences in anticipatory cortical activity and encoding of emotional stimuli by requesting participants complete an encoding task involving pleasant, unpleasant, and neutral images. Women, but not men, were shown to have early cortical responses in anticipation of unpleasant stimuli, with such activity seen by Galli et al. to be indicative of different emotion regulation strategies engaged by women to manage expectations of unpleasant information relative to men (sex differences in emotion regulation are discussed below).

Overall, previous findings surrounding sex differences in electrophysiological responses to emotional stimuli are contradictory. However, when considered together, current data seems to suggest that women are more sensitive to emotional information in general, and to unpleasant stimuli in particular reflecting a negativity bias possibly as a result of their higher sensitivity to unpleasant stimuli of lesser emotional saliency.

4.2. Impact of Menstrual Phase on Emotion Processing

The menstrual cycle is divided into follicular and luteal phases. The follicular phase includes all days from the first day of menstrual bleeding to the day before ovulation and the luteal phase includes all days from the first day of ovulation to the last day before the next menstrual period. The follicular and luteal phases can further be subdivided into early, mid, and late time intervals. Estradiol levels are typically low during the early to mid-follicular phases, peak during the late follicular and early luteal phase, plateau during the midluteal phase, and fall precipitously to low levels again just prior to menstruation whereas progesterone levels are extremely low during the follicular phase, peak during the midluteal phase, and then fall sharply to low levels during the late luteal phase (Becker et al., 2006).

Recent neuroimaging studies have demonstrated increased limbic network (amygdala and hippocampus) activation to emotionally arousing stimuli in women during their midluteal menstrual phase relative to women in their early follicular menstrual phase (Andreano & Cahill, 2010; Bayer et al., 2014; Gingnell et al., 2012). Moreover, greater activity in the amygdala and the hippocampus following an exogenous dose of progesterone corresponding to levels observed naturally during the midluteal menstrual phase has also been found (van Wingen et al., 2008). While such neuroimaging studies have emphasised menstrual phase effects on neural processes, they are limited as they do not permit the temporal processes involved in the interaction between menstrual phase and emotion processing to be explored. In contrast, high temporal resolution ERP methodology allows examination of sex differences in preconscious (automatic) and conscious neural indices of emotion processing.

Little ERP research to data has investigated menstrual phase effects on emotion processing and these studies have reported conflicting findings. Using an oddball paradigm Wu et al. (2014) examined the processing of neutral and moderately and highly unpleasant visual stimuli during the mid-late luteal and mid-late follicular menstrual phases. Wu et al. showed that N2 amplitude was greater to both moderately and highly unpleasant stimuli compared to neutral stimuli in the mid-late luteal phase, while no difference was observed during the mid-late follicular phase. The findings from Wu et al. provide support for a negativity bias in women, and indicate that the processing bias is particularly evident in midluteal women, which converges with recent neuroimaging results (e.g., Andreano & Cahill, 2010). Other ERP studies have found LPP amplitude to be greater during the mid-late luteal phase compared to the early follicular and late follicular phases to neutral and emotional stimuli (Zhand et al., 2013). Such a result may suggest that midluteal women display enhanced processing of all visual stimuli rather than a negativity bias to unpleasant stimuli specifically. Although ERPs constitute a valuable research method, there are relatively few ERP studies that have examined menstrual phase modulation of visual emotion processing.

CHAPTER 5: EMOTIONAL REACTIVITY AND EMOTION REGULATION

5.1. Emotional Reactivity and Emotion Regulation

An individual’s ability to effectively regulate emotions through the use of adaptive emotion regulation strategies has been associated with various psychological, physical, and socially positive outcomes such as reduced stress, reduced distress and experience of negative emotions, and reduced autonomic arousal and limbic system activation (Gross & Thompson, 2007, Hajcak, MacNamara, & Olvet, 2010). Emotion dysregulation or use of maladaptive emotion regulation strategies are believed to contribute to various psychopathologies such as anxiety, mood, borderline personality disorder, and substance-use disorders (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Nolen-Hoeksema, 2012). Possible mechanisms underlying the female vulnerability for anxiety may therefore be heightened or disrupted emotional reactivity or deficits in the regulation of negative emotional states. Thus, differences in emotional responding between women and men may be the result of differences in emotional reactivity, in how emotions are regulated, or some interaction between emotional reactivity and emotion regulation (McRae et al., 2008). These proposed mechanisms warrant investigation in the current research project (e.g., Aldao & Nolen-Hoeksema; Cisler & Koster, 2010; Etkin, 2009; Farb et al., 2012; Gross & Jazaieri, 2014; Kring & Sloan, 2010; Mennin et al., 2007; Price & Drevets, 2012; Waugh et al., 2012).

Emotion regulation refers to a heterogeneous set of processes that modulate the duration, intensity, experience, and expression of emotions (Gross & Ochsner, 2005). More specifically, emotion regulation describes the regulation of emotional experiences towards emotionally salient stimuli, and involves both early emotional reactivity and later emotion regulation components (Gross et al., 2011). Early emotional reactivity refers to the preconscious processing and automatic allocation of attention to emotionally salient stimuli (Lithari et al., 2010), with such reactivity being an important automatic precedent of later emotion regulation (Gross et al., 2011). Emotion regulation involves the conscious regulation of one's response to emotionally pertinent stimuli whereby emotional responses to emotion-inducing stimuli may be increased, decreased, or maintained following the use of emotion regulation strategies (Gross, 2007; Gross et al., 2011; Sheppes & Gross, 2012).

5.2. Models of Emotion Regulation

5.2.1. Modal Model of Emotion

The modal model of emotion suggests that the generation of emotions occurs in a particular 'Situation – Attention – Appraisal – Response' sequence over time (see Figure 1-a). This sequence thus begins with a situation (real or imagined) that is emotionally relevant, to which attention is directed, and allows the emotional situation to be evaluated and interpreted. This occurs before an emotional response is generated, giving rise to loosely coordinated changes in experiential, behavioural, and physiological response systems (see Gross, 1998; Gross & Thompson, 2007; Gross, 2013). As an emotional response can produce changes to a situation, the modal model involves a feedback loop from response to situation, with the loop suggesting that the emotion generation process can occur recursively, is ongoing, and dynamic (Gross, 2013).

5.2.2. Process Model of Emotion Regulation

Building upon the modal model, the process model of emotion regulation (PMER; Gross & Thompson, 2007; Gross, 2013) proposes that each of the four points in the emotion generation process can be subjected to regulation. From this conceptualisation, the PMER posits five families of emotion regulation that correspond to the regulation of a particular point in the emotion generation process (see Figure 1-c; Gross, 2013).

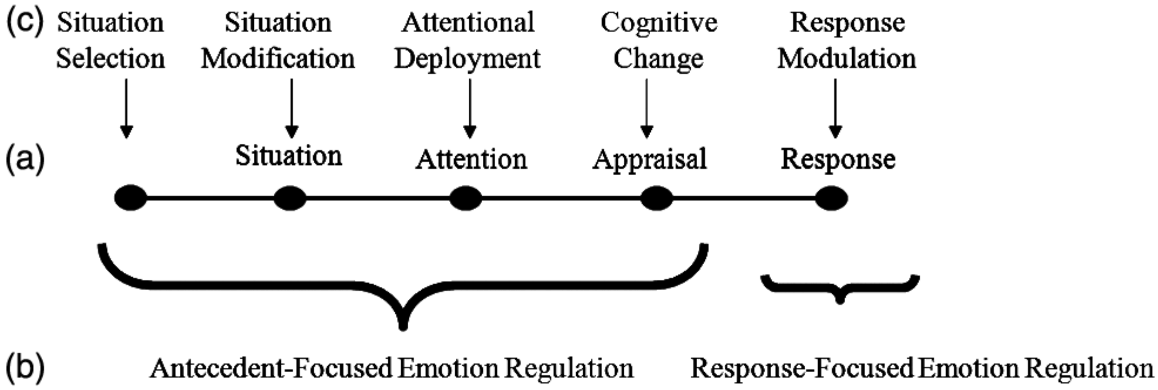

Figure 1. The process model of emotion regulation (adapted from Gross & Thompson, 2007). *Note.* (a) Components of emotion generation as outlined in the modal model. (b) Antecedent-focused versus response-focused emotion regulation strategies. (c) Five emotion regulation families.

Firstly, situation selection describes an individual choosing to approach or avoid a situation which is emotionally arousing (Gross, 2013). Secondly, situation modification involves altering the external, physical environment of an emotion situation so as to modify its emotional impact (Gross). Thirdly, attentional deployment occurs when an individual directs their attention towards or away from an emotional situation to reduce the intensity of negative emotions experienced (Campbell-Sills & Barlow, 2007; Gross & Thompson, 2007; Gross). Fourthly, cognitive change involves changing how one appraises a situation so as to alter its emotional meaning (Ayduk & Kross, 2010; Samson & Gross, 2012). Finally, response modulation involves attempts to directly influence experiential, behavioral, and physiological response systems (Gross).

The PMER divides emotion regulation strategies into two categories: antecedent-focused and response-focused (see Figure 1-b). Antecedent-focused strategies (i.e., situation selection, situation modification, attentional deployment, and cognitive change) alter emotional responses prior to emotion response tendencies being formed. In contrast, response-focused strategies (i.e., response modulation) alter the actual expression of an emotional response after response tendencies have been formed (Gross & Thompson, 2007).

When considering the generic timing hypothesis proposed by the PMER, antecedent-focused strategies, such as reappraisal, are seen to be more effective than response-focused strategies as they modify emotion early in the emotion-generation process while emotions are still gaining strength. For example, reappraisal involves cognitive modification of emotional responses by consciously altering and reinterpreting the meaning of an emotion inducing event or experience to decrease its emotional influence (Goldin et al., 2008).

In contrast, response-focused strategies, such as suppression, are a less adaptive strategy as they intervene late in the emotion-generative process when emotions have gained strength (Gross & Thompson). Suppression involves behavioural strategies for the reduction of emotionally expressive behaviour such as inhibiting and concealing emotions as they arise, thereby modulating one's response but not one's emotional experience (Gross & John, 2003; Hajcak & Nieuwenhuis, 2006). Suppression can thus lead to a paradoxical increase in negative affect and physiological arousal compared to reappraisal which generally leads to decreased physiological, subjective, psychological, and neural responding (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Etkin & Wager, 2007; Hofmann et al., 2012; Jackson, Malmstadt, Larson, & Davidson, 2000; Webb, Miles, & Sheeran, 2012).

5.2.3. Process-specific Timing Hypothesis

According to the PMER's generic timing hypothesis, all forms of emotion regulation strategies are more easily and effectively executed when emotions have low relative to high levels of intensity (Gross & Thompson, 2007). However, an alternative 'process-specific timing hypothesis' was proposed by Sheppes and Gross (2011). In this model different forms of emotion regulation are seen to be differentially sensitive to the intensity an emotional response has reached before regulation attempts are initiated. It is argued that this is because different regulation strategies modulate the emotional response at differing processing stages. The process-specific timing hypothesis is informed by information processing theories which contend that people have a limited cognitive processing capacity. This then results in competition among different sources of information at early and late processing stages. Hence, the intensity of an emotional response is impacted by whether it is blocked by an early or late selection filter (for detail see Figure 2; Sheppes & Gross). According to Sheppes and Gross, emotion-generative and emotion-regulatory processes can compete at both early and late stages of processing, *and the later the emotion-regulatory process is initiated, the more likely it will be influenced by the level of emotional intensity*. More specifically, the effectiveness of emotion regulation strategies which target early processing stages are argued to be relatively unaffected by emotional intensity level as they replace existing and incoming emotional information with minimal cognitive effort. In comparison, the effectiveness of emotion regulation strategies which target late processing stages are influenced by the level of emotional intensity as they require substantial cognitive effort to modify existing and incoming emotional information (Sheppes & Gross). This suggests that response-related suppression processes will be more affected by emotion reactivity than reappraisal processes. The process-specific timing hypothesis thus specifies a relationship between emotion reactivity and later regulation in that emotion regulation strategies are less effective when emotion intensity levels (e.g., heightened emotional reactivity) are high.

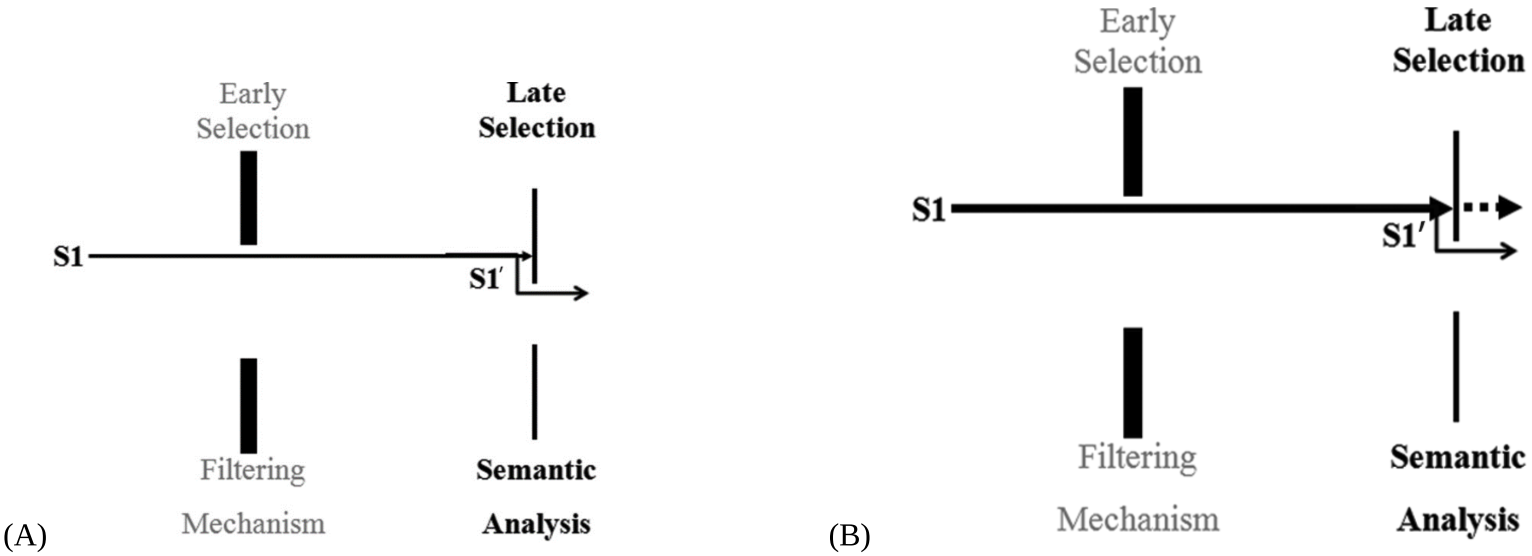

Figure 2. Process-specific timing hypothesis for reappraisal during (A) low emotional intensity and (B) high emotional intensity (adapted from Sheppes & Gross, 2011). *Note*. (a) The thickness of each filter reflects its strength and is inversely related to its use of cognitive resources. Thus, the early filter is stronger and uses fewer resources than the late filter. (b) The thickness of each arrow represents its relative strength, with thicker arrows inducing stronger influence on the final response, which is represented in the right side of the figure. (c) In reappraisal, existing and incoming emotional information are treated in the same way (indicated by a single S1 notation for both types of emotional information). (A) Low intensity levels of existing and incoming emotional information (thin arrow S1) are successfully modified with a dependent neutral reinterpretation (thin arrow S1') via the late selection filter. The neutral reinterpretation dominates the final response. (B) High intensity existing and incoming emotional information (thick arrow S1) are not fully modified by a dependent neutral interpretation (thin arrow S1') via the late selection filter. As a result, emotional information passes through the late selection filter (indicated by a dashed arrow that passes through the late selection filter and affects the response). Therefore, the dependent neutral reinterpretation of the emotional information (thin arrow S1') only partially affects the final response and is being outweighed by the strong emotional information.

5.3. Emotion Regulation: Evidence

5.3.1. Emotion Regulation: Behavioural and Physiological Evidence

Most behavioural and physiological studies examining the impact emotion regulation have typically demonstrated changes either in experiential (self-report) measures of emotional experience, or changes in facial expressiveness (i.e., startle eyeblink and facial EMG). Jackson, Malmstadt, Larson, & Davidson (2000) found that instructions to decrease negative emotions resulted in smaller startle eyeblinks and decreased EMG activity, whereas instructions to increase negative emotions led to larger startle eyeblinks and increased EMG activity. Similarly, Dillon and LaBar (2005) presented participants with unpleasant, pleasant, and neutral images and instructed them to increase, decrease, or maintain their emotional responses. On emotional picture trials, enhanced startle responses were found when participants increased their emotional response, while they were reduced when emotional responses were decreased. In another study, compared to a maintain emotion response instruction, Deveney & Pizzagalli (2008) found EMG activity to be greater following an increase emotional response instruction but decreased following a reduce emotion response instruction. However, while participants had faster, and more accurate responses to unpleasant relative to neutral stimuli, no effect of emotion regulation instruction on reaction time or accuracy was observed (Deveney & Pizzagalli). One shortcoming of many prior studies (e.g., Dillon & LaBar; Jackson et al.) is that they have collected self-report data at the exclusion of physiological responses, or measured physiological responses and excluded ‘online’ measures of self-reported emotional experience during emotion regulation. Self-report and physiological measures are both vulnerable to response biases. More specifically, self-report can be influenced by factors such as task or experimenter expectations and demands while physiological responses can be modulated by attention in addition to emotion (Bradley, Codispoti, & Lang, 2006).

Subsequently, studies have increasingly employed a multi-componential approach that operationalises emotion in terms of experience, expression, and physiology to more accurately examine regulation of emotion. For instance, Eippert, Viet, Weiskopf, Birbaumer, and Anders (2007) collected self-report, startle eyeblink, and skin conductance responses while participants increased or decreased their emotional responses to unpleasant images using reappraisal. Participants were shown to rate their emotional experiences induced by the unpleasant stimuli as more negatively valenced and more arousing than the experience induced by the neutral stimuli. Eippert et al. also demonstrated greater startle eyeblink and skin conductance responses when participants were instructed to increase their emotional responses, however modulation of eyeblink or skin conductance responses was not consistently observed when participants decreased their emotional responses. Goldin et al. (2008) measured self-reported emotion experience ratings and facial expression of disgust to examine the effectiveness of reappraisal and suppression regulation instructions to unpleasant film stimuli. Relative to instructions to maintain emotional response, reappraisal and suppression regulation strategies were both shown to reduce both the experience of emotion and facial disgust expressions. A further study by Ray, McRae, Ochsner, and Gross (2010) required participants to increase, decrease, or maintain their emotional responses to unpleasant and neutral images using reappraisal regulation strategy. Ray et al. collected mutiple measures of emotional responding including experiential (self-reported negative affect), expressive (corrugator EMG), and physiological (startle eyeblink) data. Up-regulation of emotional response resulted in greater self-reported negative affect, startle responses, and EMG activity in response to both unpleasant and neutral stimuli, whereas down-regulation led to lower levels of reported negative affect, and smaller EMG responses to unpleasant and neutral stimuli. More recently, Baur, Conzelmann, Wieser, and Pauli (2015) investigated the effects of freely chosen emotion regulation strategies (i.e., no specific regulation instructions were provided to participants) and assessed stimuli valence and arousal ratings and facial EMG responses. They showed that stimuli ratings and EMG activity increased when participants up-regulated their emotional responses and decreased when participants reduced their emotional responses. Overall, behavioural and physiological studies show that individuals can change their self-reported experience of emotion-inducing stimuli and modify the magnitude of startle eye blink and EMG responses as instructed when regulating their emotion responses to emotional (and neutral) stimuli.

5.3.2. Emotion Regulation: Neuroimaging Evidence

To allow mapping of the neural networks stimulated during the regulation of emotion, neuroimaging studies have been conducted to measure cortical and subcortical activation during emotion regulation tasks. Ocshner et al. (2004) required participants to maintain, or use cognitive reappraisal to increase or decrease their emotional responses to neutral and unpleasant stimuli. Similarly, in the study by Phan et al. (2005), participants maintained or decreased, through cognitive reappraisal, their emotional responses while they passively viewed highly arousing unpleasant stimuli. Despite different task designs, common brain regions were shown to be activated including increased activity in the prefrontal cortex, including in the superior, lateral, and orbital prefrontal regions, and the anterior cingulate cortex, and decreased activity in the limbic-related regions, including the amygdala, the nucleus accumbens, and the insula (Oschner et al., Phan et al.).

Although the prefrontal cortex has been implicated in the cognitive regulation of emotion, the cortical-subcortical interactions that mediate this ability remain poorly understood. However two seperable subcortical pathways have been reported to explain ~50% of the reported variance in self-reported emotion regulation: a path through nucleus accumbens that predicted *greater* reappraisal success, and a path through ventral amygdala that predicted *reduced* reappraisal success (i.e., more negative emotion). These results provide direct evidence that the ventrolateral prefrontal region is involved in both the generation and regulation of emotion through different subcortical pathways, suggesting a general role for this region in appraisal processes (Wager et al., 2008).

More recently, Frank et al. (2014) conducted an activation likelihood estimation meta-analysis of fMRI studies to investigate the network of neural structures activated during emotion regulation and to examine the consistency of activated structures during up-regulation and down-regulation (using reappraisal and suppression) of emotional response. Frank et al. found signal changes in the bilateral amygdala/parahippocampal gyrus that increased during up-regulated processing and decreased during down-regulated processing, while greater activity during all regulation conditions was revealed in cortical structures such as the superior frontal gyrus, cingulate, and premotor areas. These results were seen as evidence for the role of amygdala activity in experienced emotional intensity, where intentional increasing and decreasing of emotional response is initiated. Frank et al. also demonstrated that distinct subsets of frontocortical structures are involved during the execution of emotional up-regulation and down-regulation.

Neuroimaging research has also been conducted to investigate the neural correlates involved during reappraisal and suppression of negative emotion. Comparing the neural effects of reappraisal and suppression instruction to unpleasant films using fMRI, Goldin et al. (2008) demonstrated early prefrontal cortical activation, and decreased amygdala and insular activity to be elicited during reappraisal, whereas late prefrontal cortex activity and increased amygdala and insular response was elicited during suppression. While these findings are in line with the predictions of the PMER's generic timing hyothesis as suppression was found to increase activation in emotion-generative brain regions, the Goldin et al. study is limited by the failure to control for sex differences.

5.3.3. Emotion Regulation: Electrophysiological Evidence

Only a relatively small number of ERP studies have been conducted investigating emotion regulation. Examining the effect of instructions to intentionally modulate emotional responses on electrophysiological activity elicited by highly arousing unpleasant stimuli, Moser, Hajcak, Bukay, and Simons (2006) had participants suppress, enhance, or maintain their emotional responses to the unpleasant stimuli. Their results revealed significantly decreased LPP amplitude during suppression of emotional response which demonstrated that ERPs are sensitive to emotion modulation and regulation processes. Moser, Krompinger, Dietz, and Simons (2009) investigated ERP modulation during anticipation and processing of unpleasant stimuli following instructions to decrease or increase negative emotion. The results of this study showed that instructions to increase and decrease negative emotions to unpleasant stimuli impacted the amplitude of the LPP component in the direction of emotional intensity. Decrease instruction was also shown to produce enhanced frontal negativity associated with orienting and preparation prior to stimuli onset. In addition, LPP modulation began prior to regulation effects indicating that appraisal of emotion occurs before regulation of emotion. Moser et al. (2009) concluded that their findings highlight the benefit of ERPs in clarifying the time course of emotion modulation and regulation. Finally, Moser, Most, and Simons (2010) examined LPP modulation in response to viewing unpleasant emotional stimuli under instruction conditions where they required participants to decrease, increase, or maintain their emotional response to the unpleasant stimuli. Moser et al. (2010) demonstrated that LPP amplitude was decreased following reappraisal instructions to decrease negative emotion and enhanced with reappraisal instructions to increase negative emotion. Overall, while these studies provide evidence of emotion regulation instruction modulation of cortical processing, they are constrained by the failure to control for differences in emotion regulation between men and women.

5.4. Sex Differences in Emotion Regulation: Evidence

As reviewed above, heightened emotional reactivity to unpleasant stimuli is argued to reflect a negativity bias in women where women are more emotionally sensitive and responsive to unpleasant stimuli, events, and experiences than men. Such emotional reactivity possibly impacts differences between men and women in later emotion regulation (Sheppes & Gross, 2012). When considering sex differences in emotion regulation strategies, variences in the regulation of emotion between men and women has rarely been addressed, and research to date has almost exclusively employed behavioural or neuroimaging methodology and inconsistent findings have been reported. In addition to inconsistencies in behavioural and neuroimaging studies, there is a lack of electrophysiological research examining sex differences in emotion regulation.

5.4.1. Sex Differences in Emotion Regulation: Behavioural and Psychophysiological Evidence

Investigating self-report ratings of negative affect while participants completed a reappraisal task, McRae et al. (2008) revealed comparable reductions of negative affect between women and men. In contrast, Mak, Hu, Zhang, Xiao, and Lee (2009) required participants to reduce their emotional response to unpleasant stimuli with no specific regulation strategy instructions. They showed that women reported more negative affect and greater difficulty when regulating their emotional response than men. Women were also found to use more emotion-focussed coping while cognitive coping strategies were used by men. Similar findings were reported by Kong et al. (2014) who investigated sex differences in emotion regulation ability rather than in regulation strategy. Kong et al. found men to score higher in emotion regulation ability than women, a finding which supports previous research (e.g., Kong, Zhao, & You, 2012). Another emotion regulation study examining down-regulation of emotional response to unpleasant stimuli using reappraisal strategy found no differences between men and women in valence and arousal ratings of the unpleasant stimuli (Domes et al., 2010).

5.4.2. Sex Differences in Emotion Regulation: Neuroimaging Evidence

McRae et al. (2008) examined neural activity while participants completed a reappraisal task and found amygdala activation during emotion regulation to be significantly reduced in men relative to women. McRae et al. concluded that this result indicated that men expend less effort when regulating their emotions, and therefore have increased capacity to regulate unpleasant emotional responses relative to women. In addition to decreased amygdala activity, men were also shown to display less activation of prefrontal regulatory networks involved in emotion regulation as compared to women. This was seen to reflect a more efficient and less effortful emotion regulation capacity in men compared to women (McRae et al.; also see Whittle et al., 2011). Conversely, Domes et al. (2010) conducted another neuroimaging study investigating reappraisal of unpleasant stimuli and showed prefrontal region activity to be greater in men relative to women, with no sex differences in amygdala activation observed. This led Domes et al. to conclude that men may not possess a more efficient emotion regulation processing system as was argued by McRae et al.

Mak, Hu, Zhang, Xiao, and Lee (2009) presented evidence that men and women use different regulation strategies and differ in brain activation, even when not provided with specific emotion regulation instructions. During a task where participants were given a general instruction to down-regulate their emotional response to unpleasant stimuli, Mak et al. (2009) found that men exhibited stronger activation in the left lateral orbitofrontal gyrus, left superior frontal gyrus, right anterior cingulate gyrus, left middle temporal gyrus, and temporal pole when regulating negative emotion. In contrast, women only displayed stronger activation in the left medial orbitofrontal gyrus relative to men. The results were interpreted as suggesting that the brain regions engaged by women to regulate negative emotion were associated with emotion processing, while the regions stimulated in men were more associated with cognitive processing, with this interpretation supported by self-report ratings where women reported using more emotion-focused coping while men use more cognitive coping strategies as previously noted (Mak et al.).

Extending on previous neuroimaging studies outlined above, Wu et al. (2016) investigated how sex differences in emotion regulation are manifested in brain networks which are seeded on the amygdala subregions. They showed that men and women differ in the neural circuits associated with emotion generation, representation, integration, and regulation. Specifically, women, when compared to men, showed a stronger negative resting-state functional connectivity between the right centromedial amygdala and the medial superior frontal gyrus, and stronger positive RSFC between the right centromedial amygdala and the anterior insula and the superior temporal gyrus (STG).

Similarly, Kong et al. (2014) used structural magnetic resonance imaging (MRI) to assess sex differences in emotion regulation ability rather than strategy to demonstrate evidence of sex differences in the neuroanatomical basis of emotion regulation ability. Women were shown to have a connection between emotion regulation ability and regional gray matter volume (rGMV) in the area between the left brainstem and the left hippocampus, while men exhibited a relationship between emotion regulation ability and rGMV in the right dorsolateral prefrontal cortex. Discrepancies in reported neuroimaging results may result from the low temporal resolution of neuroimaging methods which limits the accurate delineation of temporal processes associated with early emotional reactivity and later emotion regulation.

5.4.3. Sex Differences in Emotion Regulation: Electrophysiological Evidence

The author is only aware of one ERP study investigating sex differences in emotion regulation that has been conducted to date. Gardener, Carr, MacGregor, and Felmingham (2013) examined sex differences in early emotional reactivity (reflected by N1 and N2 components) and later emotion regulation (reflected by P3 and LPP components) by instructing participants to maintain or use reappraisal to increase or decrease their emotional response during passive viewing of unpleasant stimuli. Their results demonstrated that women had significantly greater N1 and N2 amplitudes to the unpleasant stimuli compared to men. While P3 was not shown to be modulated by emotion regulation, LPP amplitudes were greater to the increase instruction, and women displayed greater LPP amplitudes relative to men to the increase instruction. These findings were interpreted to reflect a female negativity bias during early processing and indicated that women have greater up-regulation of emotional responses to unpleasant stimuli relative to men. Hence, the influence of sex differences on emotion regulation processes, as reflected in cortical electrophysiological activity, is an area which requires further investigation given the shortage of previous ERP emotion regulation studies.

5.5. Impact of Menstrual Phase on Emotion Regulation

As menstrual phase modulation of the limbic network has been demonstrated (Andreano & Cahill, 2010), there is a need for further research to examine whether menstrual phase impacts emotion regulation processing. However, as outlined above, only a handful of ERP studies have investigated the effect of menstrual phase on emotion processing and these studies have reported inconsistent findings (e.g., Wu et al., 2014; Zhang et al., 2013). Of importance is that few ERP studies have extended existing sex differences and emotion literature to investigate sex differences in emotion regulation. N1 and N2 amplitudes have been shown to be increased in women relative to men (Lithari et al., 2010) irrespective of emotion regulation instruction (Gardener et al., 2013).

Activation of the P3 ERP component has been found to reflect modulation of emotional responses prior to later emotion regulation processes (Moser et al., 2009; Olofsson et al., 2008). Further, LPP amplitude has been shown to be lower when one's emotional response is decreased and higher when emotional reactivity is increased (Hajcak & Nieuwenhuis, 2006; Moser et al.). Gardener et al. revealed that LPP amplitude in response to an 'increase' emotion instruction was greater in women compared to men, whereas sex differences to a 'decrease' emotion instruction were not found. Taken together, these ERP findings are indicative of increased early emotional reactivity and greater engagement of emotion regulation processes in women compared to men. However, as will be discussed in Chapter 5, despite growing evidence regarding the relevance of sex hormones for emotional processing (Toffoletto et al., 2014), no ERP emotion regulation studies to date have previously investigated sex differences and the impact of menstrual phase on emotion regulation processing.

CHAPTER 6: IMPLICATIONS AND AIMS FOR THE PROGRAM OF RESEARCH

6.1. Implications for the Program of Research

Two key theories of emotion processing have been developed; the motivational model and the negativity bias hypothesis. The motivational model proposes generally enhanced processing of emotional (pleasant and unpleasant) relative to neutral stimuli (e.g., Lang, et al., 1997), whereas the negativity bias hypothesis stipulates the prioritised processing of unpleasant relative to pleasant and neutral stimuli (e.g., Cacioppo et al., 2011). While some evidence for the motivational model has been reported, recent ERP evidence provides stronger support for a negativity bias in women (e.g., Li et al., 2008; Lithari et al., 2010; Gardener et al., 2013). The first aim of this thesis was to test the competing hypotheses of the motivational model and negativity bias hypothesis in the context of sex differences to assess whether women exhibit greater negativity bias or greater emotionality response in general. The recent ‘process-specific timing hypothesis’ developed by Sheppes and Gross (2011) highlights the important role of emotional reactivity in subsequent emotion regulation, as emotion regulation strategies are argued to be less effective when emotional reactivity levels are high. However, very few ERP studies have investigated sex differences in emotion regulation. Following the Sheppes and Gross model, a second aim of the thesis was to examine sex differences in emotional reactivity and how it may impact on later emotion regulation processing by using high-temporal resolution ERP methodology to explore the cortical indices of emotional reactivity and emotion regulation.

6.2. General Aims of the Program of Research

Due to the lack of theoretical and empirical consensus as outlined above, Chapter 7 of this thesis outlines the research investigating the fundamental question of whether women are more reactive to emotional stimuli in general (motivational model), or whether their responding reflects a specific reactivity to unpleasant/threat stimuli (negativity bias) (Study 1). Women have a vulnerability for anxiety disorders and demonstrate heightened aversive system activation whereas men exhibit greater appetitive system activation (Bradley & Lang, 2010; Kessler et al., 2005; McLean et al., 2011; Stevens & Hamann, 2012). Accordingly, in line with the negativity bias hypothesis it was predicted that women would display greater cortical reactivity to unpleasant than pleasant or neutral stimuli (reflected in higher P1, N1, N2, P3 and LPP amplitudes) compared to men.

As discussed in Chapter 8, whilst menstrual phase, particularly the midluteal phase, is increasingly being recognised as an important factor to consider within the emotion processing research domain (e.g., Toffoletto et al., 2014; Wu et al., 2014), there is little ERP research examining the impact of menstrual phase on emotion processing, and inconsistent findings have been reported in these studies. Accordingly, Study 2 aimed to extend the theoretical basis of Study 1 by investigating the question of whether midluteal women exhibit a negativity bias to unpleasant stimuli specifically or have heightened responsiveness to emotional stimuli in general, in comparison to men and to women in their early follicular menstrual phase. If emotion processing during the midluteal phase reflects a negativity bias, ERP amplitudes to unpleasant relative to pleasant and neutral stimuli were anticipated to be greater for midluteal women as compared with men and early follicular women. On the other hand, if greater processing of emotional stimuli in general is demonstrated during the midluteal phase, ERP amplitudes were predicted to be increased to the pleasant and unpleasant compared to neutral stimuli for midluteal women relative to early follicular women and men.

As emotional reactivity influences on later emotion regulation, and deficits in regulating negative emotion is implicated in anxiety and depressive disorders, for which women display vulnerability relative to men (Cisler & Koster, 2010; Etkin, 2009; Farb et al., 2012; Mennin et al., 2007; Price & Drevets, 2012; Waugh et al., 2012), Chapter 9 examined sex differences in cortical activity during early emotional reactivity and later emotion regulation processes controlling for menstrual phase (Study 3). In line with the negativity bias hypothesis and with consideration of research which demonstrates midluteal phase modulation of emotion processing (e.g., Wu et al., 2014), women in their midluteal menstrual phase were predicted to show greater early emotional reactivity to unpleasant stimuli, indicating an early negativity bias, relative to women in their early follicular menstrual phase and to men, with this reflected by enhanced P1 and N1 component amplitudes. It was further anticipated that this sensitivity to unpleasant stimuli would influence later emotion regulation processes. Specifically, we expected midluteal women to exhibit greater difficulty in down-regulating their responses to unpleasant stimuli in response to emotion regulation instructions (reappraisal, and particularly suppression), as reflected by smaller reductions in P3 and LPP amplitudes, compared to early follicular women and men.

CHAPTER 7: SEX DIFFERENCES IN THE CORTICAL PROCESSING OF EMOTION

Sex Differences in the Cortical Processing of Emotion

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7.1. Abstract

A fundamental question in the sex differences and emotion field is whether women are more cortically reactive to emotional stimuli in general (motivational model) or whether their responding reflects a specific sensitivity to unpleasant/threat stimuli (negativity bias). To test these competing models, event-related potentials (ERPs) were recorded from 40 (n=20 women) participants during a dual oddball task comprising 240 images (80 pleasant, 80 unpleasant/threat, 80 neutral). Women rated the unpleasant/threat stimuli as more arousing than did men. Women displayed greater N2 amplitude to neutral and unpleasant stimuli relative to pleasant stimuli, while men showed greater N2 amplitude to neutral compared to both unpleasant and pleasant stimuli, with unpleasant stimuli shown to be higher than pleasant stimuli. Irrespective of sex, P3 amplitude was greater to pleasant and unpleasant compared with neutral stimuli. LPP amplitudes were shown to be greater to pleasant and unpleasant relative to neutral stimuli for both women and men during the dual-task condition, with women shown to have significantly greater LPP amplitude than men to all valences. While no support was found for the negativity bias, some support for the motivational model was demonstrated during late (P3, LPP) processing. Taken together, these results provide some evidence for the motivational model, but generally reveal few sex differences to emotional stimuli, and there is little evidence for a female negativity bias. This finding is somewhat divergent from previous literature and may have resulted from methodological factors.

7.2. Introduction

Large-scale epidemiological studies consistently reveal that women typically develop anxiety disorders at twice the rate of men (Australian Bureau of Statistics, 2007, 2015; Kessler et al., 1994, 2005; McLean et al., 2011). Despite this prevalence, the mechanisms underlying this female vulnerability remain unknown. One possibility is that women display greater emotional reactivity than men (Stevens & Hamann, 2012). Two dominant theoretical models of affective processing exist. The motivational model of attention and affective states (motivational model) proposes a biphasic perspective. Specifically, stimulus valence elicits activation in underlying appetitive and aversive systems which drive pleasant emotional states and approach behaviours, and unpleasant emotional states and avoidance respectively (Lang & Bradley; Lang, Bradley, & Cuthbert, 1997). Valence is argued to reflect initial selective attention capture by salient image content as determined by the dominant motive system, while arousal is thought to reflect the level of energy and activation mobilised within each system during the processing of emotional stimuli (Lang & Bradley, 2010; Lang et al.). Davidson et al. (2002) extended the motivational model to propose the appetitive system led to activation predominantly in the left, and the aversive system in the right hemisphere. The motivational model predicts greater cortical reactivity to both unpleasant and pleasant stimuli compared to neutral stimuli (Cuthbert et al., 2000) and several ERP studies report an inverted ‘U’ function of arousal and valence (related in a nonlinear manner) consistent with this model (e.g., Cuthbert et al.; Keil et al., 2002; Schupp et al., 2003).

In contrast, the negativity bias hypothesis proposes that aversive system activation is greater than appetitive system activation in response to equally intense appetitive and aversive cues (Ito & Cacioppo, 2005; Ito, Cacioppo, & Lang, 1998). One of the key assumptions underlying the negativity bias is the notion of 'negative potency', which refers to the idea that highly unpleasant stimuli and events are more threatening than equally intense pleasant stimuli and events are positive. Specifically, negative stimuli/events are experienced with increased emotional reactivity than pleasant stimuli/events, and responses to unpleasant events are typically more varied which subsequently results in a larger influence of unpleasant events/stimuli (Rozin & Royzman, 2001). Therefore, the negativity bias hypothesis predicts greater cortical reactivity to unpleasant compared to pleasant and neutral stimuli (Cacioppo & Berntson, 1994; Ito & Cacioppo). A fundamental question in this field is whether women are more cortically reactive to emotional stimuli in general (in line with the motivational model), or whether their responding reflects a specific sensitivity to unpleasant/threat stimuli (reflecting a negativity bias).

Previous behavioural, physiological, and neuroimaging studies have shown that men and women differentially process emotional stimuli. Men have been shown to rate pleasant stimuli, particularly erotic stimuli, as significantly more pleasant and arousing (e.g., Bianchin & Angrilli, 2012; Bradley & Lang, 2007; Bradley et al., 2001a; Chivers et al., 2010; Lang et al., 1997; Rozenkrants & Polich, 2008b; Rupp & Wallen, 2008; Sabatinelli et al., 2004; Sass et al., 2010). Conversely, women have been found to have faster reaction times and higher accuracy to emotive (predominantly unpleasant) stimuli relative to men (e.g., Li et al., 2008; Whittle et al., 2011), and have greater self-reported arousal and unpleasantness ratings of unpleasant stimuli compared to men (e.g., Bradley et al., 2001b). Women have also been shown to exhibit greater physiological reactivity compared to men as demonstrated by higher levels of fear bradycardia (i.e., immobility and sustained cardiac deceleration) and greater facial electromyography activity when viewing unpleasant stimuli (Bianchin & Angrilli; Bradley et al. 2001b; Chentsova-Dutton & Tsai 2007; Hillman, Rosengren, & Smith, 2004; Kemp et al., 2004; Lang & Bradley, 2010). Skin conductance responses (SCR), which provide an index of physiological arousal, have been shown to be greater in response to stimuli depicting animal/human threat and mutilation for both men and women. However, women displayed enhanced SCR changes in response to unpleasant compared to pleasant and neutral stimuli while men showed similar responses for both pleasant and unpleasant stimuli compared to neutral stimuli (Bradley et al., 2001b). Further, while startle reflex, which is sensitive to unpleasant emotional stimuli, has been shown to be enhanced in women (Bianchin & Angrilli), other studies have failed to show sex differences in startle reflex amplitude during both appetitive and aversive conditions (e.g., Bradley et al., 2001b; Hillman, Rosengren, & Smith, 2004), indicating that sex may not influence the startle reflex.

Further, while neuroimaging research has revealed that similar brain areas are stimulated in response to pleasant and unpleasant stimuli in women and men, amygdala and visual cortex activation has been shown to be greater in men relative to women during the viewing of erotic stimuli (Hamann et al., 2004; Karama et al., 2002; Kemp, Silberstein, Armstrong, & Nathan, 2004;

Lithari et al., 2010; Sabatinelli et al., 2004; Wrase et al., 2003). When considered together, present findings are overall suggestive of greater appetitive system activation in men and increased aversive system activation in women.

Nonetheless, while extensive research into sex differences in appetitive and aversive system processing has been performed using behavioural measures (e.g., valence and arousal ratings), physiological measures (e.g., SCR, heart rate, startle reflex, facial electromyography), and neurophysiological measures (e.g., fMRI), this body of research is inconclusive and inconsistent, with inconsistencies in findings potentially arising as a result of their poor temporal resolution (Hajcak et al., 2012). Conversely, event-related potentials (ERPs) have high temporal resolution which permits the delineation of precise temporal processes associated with emotion processing and thus extension of knowledge beyond behavioural, physiological, and neuroimaging studies. However, despite their utility of offering unique insights into an emotional response over time, less experimental focus has been directed towards investigating sex differences in the electrophysiological activation involved in emotion processing.

ERPs constitute a powerful tool for exploring and providing insight into cortical mechanisms associated with emotional processing (Fabiani et al., 2000), with enhanced ERP amplitudes reflecting early emotional reactivity and later processing of emotionally salient stimuli (Carretie, Martin-Loeches, Hinojosa, & Mercado, 2001). The temporal courses of ERP valence and arousal differ whereby valence is thought to influence relatively early (100-200ms) ERP components and arousal to affect later (200-1000ms) ERP components (Codispoti et al., 2007; Gianotti et al., 2008; Olofsson & Polich, 2007; Olofsson et al., 2008; Zhang, Zhou, & Oei, 2011). Further, several ERP research studies have also associated early cortical reactivity to emotional stimuli with early ERP components, such as the P1 which is seen to reflect early preconscious visual processing when activated at occipital sites (Hillyard & Anllo-Vento, 1998; Luck et al., 2000; Olofsson et al., 2008). Early emotional reactivity has also been associated with the N1 and N2 components, which are maximal at frontal sites (Hajcak et al., 2010), and which are seen to reflect automatic preconscious and early conscious processing of emotional stimuli respectively (Lithari et al., 2010; Näätänen, 1992). The emotional ERP literature has revealed that the P3 component, maximal at parietal sites, is involved in the later conscious appraisal of emotional stimuli, and subsequent allocation of attention to emotionally salient stimuli and modulation of emotional responses prior to later emotion regulation processes (Luck, 2014; Moser et al., 2009; Olofsson et al., 2008; O'Reilly et al., 2004). Previous emotional ERP research has reported an index of later conscious processing in the Late Positive Potential (LPP) which has been found to be maximal at parietal sites (Krug et al., 2000). The LPP has been reported as a consistent, non-habituating regulative response, which is highly sensitive towards high-arousing, emotionally salient stimuli compared to neutral stimuli (Hajcak et al., 2010; Hajcak & Olvet, 2008; Hot et al., 2006; Olofsson et al.; Schupp et al., 2000).

Providing evidence for the motivational model, enhanced ERP amplitudes in response to highly arousing pleasant and unpleasant stimuli compared to low arousing or neutral stimuli have been demonstrated for both women and men (Cuthbert et al., 2000; Schupp et al., 2000). Campanella et al. (2004) demonstrated that while men and women have exhibited greater N2 reactivity to fearful faces, women also displayed greater N2 to happy faces. Studies which have examined sex differences in ERP activation to positive stimuli have reported greater cortical response to pleasant, particularly erotic, stimuli in men as compared to women (Kemp et al., 2004). However, other studies have failed to demonstrate any sex differences in the processing of either pleasant or unpleasant stimuli (Rozenkrants & Polich, 2008). ERP studies have revealed greater P3 amplitude to unpleasant compared to pleasant stimuli, in line with the negativity bias model (Delplanque et al., 2005, 2006; Ito et al., 1998). Recent ERP studies provide further evidence for a negativity bias in women, revealing that women relative to men have greater N1 and N2 amplitudes to unpleasant images (Gardener et al., 2013; Lithari et al., 2010). A further ERP study found that while both men and women displayed greater N2 and P3 amplitudes to highly unpleasant images, only women displayed greater N2 and P3 amplitudes to moderately unpleasant stimuli, reflecting greater sensitivity to unpleasant images in women (Li et al., 2008). Gasbarri et al. (2007) reported that both men and women displayed greater P3 amplitudes to unpleasant stimuli, but women displayed greater P3 amplitudes in the left hemisphere and men in the right. Given the variation in responses to emotional stimuli in women and men, the question regarding whether women display specific cortical reactivity to negative stimuli or to emotional stimuli in general requires further investigation.

In summary, two key theories have been proposed to explain the processing of emotional information, the motivational model and the negativity bias hypothesis. With respect to cortical reactivity, the motivational model predicts greater ERP component amplitudes in response to both unpleasant and pleasant relative to neutral stimuli, with women shown to have greater reactivity relative to men (Cuthbert et al., 2000). In contrast, the negativity bias hypothesis would predict greater ERP component amplitudes to unpleasant compared to pleasant and neutral stimuli, with women showing greater cortical reactivity than men (Cacioppo & Berntson, 1994; Ito & Cacioppo, 2005). This negativity bias in women is thought to result in heightened threat sensitivity, which if intense and generalised, can result in vulnerability for developing anxiety. Previously reported sex differences to emotional stimuli in behavioural, physiological, neurophysiological, and electrophysiological responses are varied and inconclusive.

Consequently, the current study aimed to explore sex differences in ERPs to pleasant, unpleasant, and neutral stimuli to investigate whether women display greater processing to negative stimuli specifically, in line with the negativity bias hypothesis, or to emotional stimuli in general, as outlined in the motivational model of emotion processing. As discussed previously, women have vulnerability for anxiety disorders (Australian Bureau of Statistics, 2007, 2015; Kessler et al., 1994, 2005; McLean et al., 2011) and have been shown to demonstrate greater aversive systen activation while men demonstrate increased appetitive system activation (e.g., Lithari et al., 2010; Rozenkrants & Polich, 2008). Accordingly, it was hypothesised, in accordance with the negativity bias hypothesis, that women relative to men would display greater cortical reactivity to unpleasant than pleasant or neutral stimuli, as reflected by larger ERP (P1, N1, N2, P3, and LPP) component amplitudes.

Alternatively, if women display enhanced emotional processing in general (in line with the motivational model), we predicted ERP amplitudes to pleasant and unpleasant relative to neutral stimuli to be greater for women as compared to men.

7.3. Method

7.3.1. Participants

Forty participants were recruited from first-year psychology undergraduates (women: n=20; age range 18-31 years, *M*=23.35, *SD* =3.28; men: n=20, age range 18-33 years, *M*=25.45, *SD*=4.71) and voluntarily participated in this research. All participants were right handed and reported normal sleep patterns, normal or corrected-to-normal vision, and no history of visual disorders. As participants were presented with images depicting erotic women, erotic men, and erotic couples, all participants were of heterosexual sexual orientation to control for potential response differences as a result of differing sexual orientation (Brewster, Mullin, Dobrin, & Steeves, 2011; Kranz & Ishai, 2006; Savic & Lindstrom, 2008). Participants who were taking medications, reported intellectual and learning disabilities, substance abuse or dependence, a history of neurological disorders, brain injury or loss of consciousness greater than five minutes, or who reported a history of psychiatric disorders or a history of phobias or phobic responses to the semantic content of experimental task stimuli were excluded from this study. All participants gave informed consent and the study had ethical approval from the Social Sciences Human Research Ethics Committee (University of Tasmania; UTAS).

7.3.2. Stimuli and Materials

7.3.2.1. Profile of Mood States

The Profile of Mood States (POMS; McNair, Lorr, & Doppleman, 1971) questionnaire was used to provide a measure of each participant's mood pre- and post- the experimental testing session. The POMS is a 65-item self-report measure which assesses psychological distress during the previous week in six domains (fatigue-inertia, vigour-activity, tension-anxiety, depression-dejection, anger-hostility, and confusion-bewilderment). Each item is measured on a five-point Likert scale (0= *not at all*, 4= *extremely*) and a total score pf psychological distress was calculated. Participants' responses and the scale scoring process were completed according to the POMS standardised instructions. The POMS is a highly reliable measure of depression (α=.92) (McNair et al., 1971).

7.3.2.2. Dual Oddball Task

As emotion categorisation, oddball, and dual-task paradigms have commonly been used in previous ERP emotion research (e.g., Campanella et al., 2004; Delplanque et al., 2004; Hajcak et al., 2012; Rozenkrants & Polich, 2008; Schupp et al., 2007), a computer-based dual-oddball paradigm was used in the current study. Emotion processing was examined by randomely presenting 240 emotional images from the International Affective Pictures System (IAPS, Lang, Bradley, & Cuthbert, 2008), with 80 neutral, 80 pleasant and 80 unpleasant scenes[1] Each valence category contained 20 images from

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[1] IAPS Images:
Neutral: 5020, 5040, 5120, 5201, 5500, 5510, 5520, 5530, 5531, 5532, 5533, 5534, 5726, 5740, 5750, 5800, 5811, 5814, 7000, 7001, 7002, 7003, 7004, 7009, 7010, 7012, 7017, 7019, 7025, 7026, 7032, 7035, 7042, 7052, 7080, 7090, 7211, 7235, 7255, 7260, 7281, 7285, 7290, 7300, 7340, 7351, 7352, 7354, 7365, 7390, 7405, 7451, 7461, 7470, 7475, 7477, 7484, 7488
Pleasant: 4001, 4002, 4003, 4005, 4006, 4008, 4085, 4090, 4130, 4141, 4142, 4180, 4279, 4232, 4235, 4240, 4290, 4300, 4310, 4320, 4460, 4470, 4490, 4503, 4505, 4520, 4530, 4538, 4550, 4561, 4604, 4611, 4647, 4651, 4652,

four semantic picture content types: Neutral: mushroom, food, household objects, trees/plants; Pleasant: erotic males, erotic females, erotic couples, sport/adventure; Unpleasant: death, human mutilation/injury, human threat, animal threat). Each valence condition contained 80 images to ensure good signal-to-noise ratios. The emotional images were selected according to IAPS valence and arousal normative data rating, in addition to selecting images that allowed for a wide range of image types: neutral valence rating was between '4' and '6.5' (*M*=5.64, SD=.78) while neutral arousal rating was between '1' and '6' (*M*=3.49, SD=.90); pleasant valence rating was between '6.5' and '9' (*M*=6.55, *SD*=.69) while pleasant arousal rating was between '4' and '7' (*M*=35.71, *SD*=.79; unpleasant images had a valence rating between '1' and '4' (*M*=2.57, *SD*=.95) and an arousal rating between '4' and '7' (*M*=6.35, *SD*=.56). The valence means for each valence category were significantly different from each other. The sex-specific ratings of the presented image categories, as provided by the IAPS collection, are presented in Table 2, accompanied by our participants' image ratings (see Appendix B for valence and arousal ratings of individual stimuli). Participant ratings were highly similar to the IAPS ratings. As there were 208 IAPS stimuli selected for this study, in order for 20 presentations of each of the 12 semantic content categories to be shown, selected stimuli were presented multiples times; all of the mushroom images were presented twice and four mushroom images were presented three times (#5500, #5520, #5531, #5532); and all of the trees/plants

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4658, 4659, 4664.1, 4668, 4669, 4670, 4672, 4677, 4690, 4693, 4694, 4695, 4660, 4800, 4810, 5621, 5622, 5623, 5626, 8030, 8031, 8033, 8034, 8041, 8065, 8117, 8118, 8161, 8163, 8179, 8190, 8200, 8250, 8325, 8370
Unpleasant: 1050, 1052, 1112, 1114, 1120, 1201, 1202, 1205, 1220, 1300, 1301, 1302, 1310, 1321, 1525, 1726, 1820, 1930, 1931, 1932, 2811, 3000, 3001, 3010, 3015, 3030, 3051, 3053, 3060, 3062, 3063, 3064, 3068, 3069, 3071, 3080, 3100, 3101, 3102, 3103, 3110, 3140, 3150, 3170, 3180, 3181, 3185, 3191, 3195, 3213, 3225, 3261, 3266, 3400, 3500, 6210, 6211, 6213, 6231, 6242, 6244, 6260, 6300, 6312, 6313, 6315, 6350, 6510, 6520, 6550, 6560, 6570.1, 6821, 8230, 9040, 9042, 9252, 9253, 9405, 9433

and erotic male images were presented twice. The same set of stimuli were used in the single and dual conditions. To ensure attention was directed to stimuli, a dual-oddball condition was presented concurrently with these emotional images on the same slide. The oddball condition comprised 16 yellow (probability 20%) and 64 blue (probability 80%) crosses centrally displayed 1.3 centimetre's below the emotional stimuli, and participants were required to mentally count the low probability yellow target crosses and ignore the blue standard crosses. Stimuli were presented for 1000ms, response window was 1500ms, and inter-stimulus interval was 2500ms.

7.3.3. Procedure

Participants attended the Cognitive Neuroscience Laboratory at UTAS for one two-hour testing session. The POMS (McNair et al., 1971) was administered before participants completed the experimental task (see Figure 1). The two conditions (emotion processing and dual-task) within the experiment were presented to participants in a counterbalanced order, with the stimuli presented randomly within each condition. The emotion processing condition required participants to respond to the emotional stimuli by pressing with their right hand as quickly as possible the number one, two, or three keys on a response pad according to whether they perceived the presented images to be unpleasant, neutral, or pleasant respectively. Participants also completed the dual-task involving the oddball condition embedded into the emotion processing condition. Participants were requested to give 100% attentional priority to stimuli targets in the emotion processing condition whereas in the dual-task participants were requested to give 50% attentional priority to each condition. During the dual-oddball condition, participants were required to mentally count the yellow targets rather than make overt responses while simultaneously categorising the emotional stimuli as outlined above (Hajcak et al., 2010). Task instructions were explained and participants completed a two minute practice trial for each condition before experimental task presentation. Following task completion, each IAPS image was then independently rated for level of valence and arousal on a 9-point Likert scale adapted from the IAPS normative data rating scale (Self-Assessment Manikin; Bradley and Lang, 1994): Valence (1 = *highly unpleasant*, 5 = *neutral*, 9 = *highly pleasant*); Arousal (1 = *not at all exciting/arousing*, 5 = *moderately arousing*, 9 = *highly exciting/arousing*). The POMS (McNair et al.) was then re-administered.

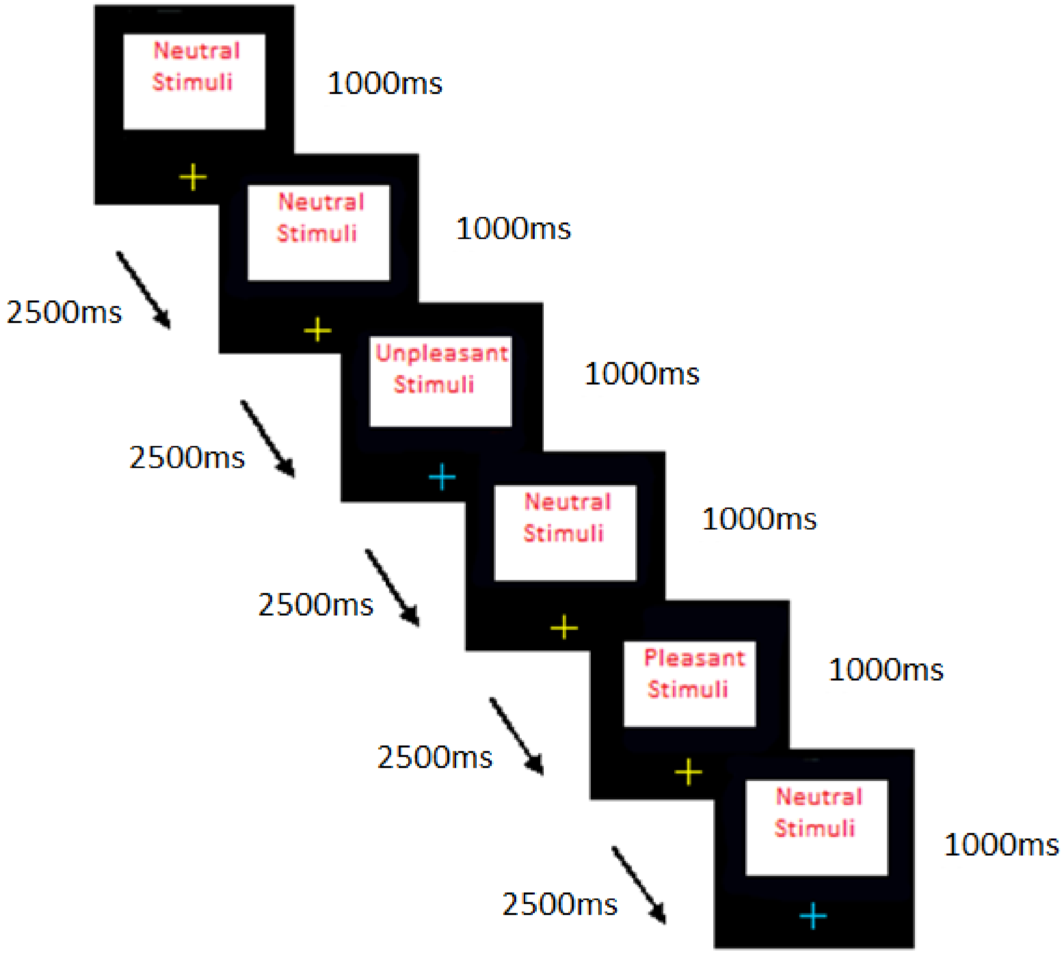

Figure 1. Flowchart of the dual-task stimulus presentation.

7.3.4. Electrophysiological Apparatus and Recording

EEG activity was recorded from 32 sites according to the international 10-20 system (Jasper, 1958) using a Quik-cap with silver/silver chloride (Ag/AgCl) electrodes and SynAmps 2 amplifiers. All electrode sites were referenced to linked mastoids and an AFz ground was used. Horizontal electro-oculographic (EOG) activity was recorded from electrodes placed at the outer canthi of both eyes, while vertical EOG activity was recorded from electrodes above and below the left eye. Electrode impedance was kept below 10KΩ and EEG data were sampled at 1000Hz and amplified with an online high pass filter of 0.15Hz and a low pass filter of 100Hz. EEG data was merged with behavioural files followed by vertical and horizontal ocular artefact reduction. The ocular artefact reduction algorithm was developed by Compumedics Neuroscan (2006) and based on combined regression analysis and artefact averaging (Semlitsch et al., 1986). Continuous data files were then low-pass filtered at 30Hz at 48dB per octave, epoched offline for a 1000ms epoch commencing 100ms before stimulus onset, and baseline corrected. High and low voltage cut-offs for artefact rejections were set at 100µV and -100µV respectively. EEG activity corresponding to each stimulus condition was averaged and filtered with a high band pass of .15Hz and a low pass of 30Hz. In accordance with previous research and a visual inspection of grand means, N1 and N2 were defined as the peak negativities within 50-150ms and 200-350ms, respectively, over frontal electrodes (F3, FZ, F4; Hajcak et al., 2010). P1 was measured as the peak positivity within 60-120ms over occipital electrodes (O1, OZ, O2; Olofsson et al., 2008). P3 was determined as the peak positivity within the 250-450ms time window over parietal sites (P3, PZ, P4;

O'Reilly et al., 2004). The LPP was defined as the mean positivity within 450-700ms over parietal sites (P3, PZ, P4; Krug et al., 2000).

Given the number of components investigated and the fact that our hypothesised differences related to the amount of cortical processing rather than speed of processing, analyses were restricted to examine component amplitude rather than the latency of components. The decision to analyse amplitude effects exclusively is in line with a majority of recent ERP studies investigating emotion processing (e.g., Althaus et al., 2014; Galli et al., 2011; Groen et al., 2013; Jin, Yan, Zhang, Jiang, Tao, & Zheng, 2013; Lin et al., 2014; Luo et al., 2014; Meng et al., 2009; Pfabigan et al., 2014; Raz et al., 2014; Syrjänen & Wiens, 2013; Wiens & Syrjänen, 2013).

7.3.5. Design and Data Analysis

Separate univariate ANOVAs with Sex as the between-subjects factor were conducted to assess any sex differences in age or pre- and post-experiment mood (as measured by the POMS total score, McNair et al., 1971) and in stimulus mean valence and arousal ratings for the pleasant, unpleasant, and neutral conditions (as measured by the picture rating task).

Peak amplitudes of P1, N1, N2, P3, and the mean amplitude of the LPP were analysed using 2[Sex: Women, Men] × 2(Condition: Single, Dual) × 3(Valence: Pleasant, Unpleasant, Neutral) × 3(Site: F3, FZ, F4 *or* P3, PZ, P4 *or* O1, OZ, O2) mixed factorial ANOVAs. Artefactual (e.g., evidence of visual or physiological artefact) electrode data values were replaced with the mean score of the surrounding electrodes (Picton et al., 2000). Two electrode channels (FP1, FP2) were classified as artefactual for all participants, but these were not channels that were analysed. Outlier checking was conducted and data-points greater than three standard deviations above the mean were identified as outliers (Tabachnick & Fidell, 2013). To maintain the range and relative ordering of scores, outliers were replaced with a value .1 below this three standard deviation cutoff range (Osborne & Overbay, 2004; Tabachnick & Fidell) and 1% of the data was replaced. Greenhouse-Geisser corrections were made where appropriate and significance levels were maintained at alpha <.05. Sidak-corrected pairwise comparisons were used to test for significant differences between individual means, where necessary and effect sizes were measured using partial eta squared (η_p^2). Data were analysed using the Statistical Package for the Social Sciences (SPSS; version 20). Obtained results involving electrode site are not reported unless involved in an interaction of hypothesised significance with Sex, Condition, or Valence (see Appendix C for full ERP analyses summary; Appendix O).

7.4. Results

7.4.1. Clinical and Demographic Data

Means and standard deviations of clinical and demographic data are presented in Table 1. As seen in Table 1, no significant differences were found between women and men in age or pre- or post-experiment mood.

Table 1

Mean Age and Mean Scores for Pre- and Post- Experiment Mood for Women and Men

Variable	Women	Men	*F*	*p*	ηp^2
Age	23.35 (3.28)	25.45 (4.71)	2.68	.11	.066
Pre-mood	34.60 (32.28)	18.20 (27.21)	3.018	.09	.074
Post-mood	21.65 (27.06)	14.85 (30.91)	.548	.46	.014

Note. Standard Deviations in parentheses.

7.4.2. Picture Rating Task

As shown in Table 2, the obtained IAPS stimuli ratings demonstrated that participants rated the experimental images in accordance with the IAPS normative data. For the arousal data, a significant main effect of Sex was found for the unpleasant stimuli, $F(1,38)=4.08$, $MSE=3.90$, $p=.05$, $\eta p^2=.097$, which demonstrated that women ($M=5.05$, $SD=1.79$) rated the unpleasant stimuli as being significantly more arousing than did men ($M=3.79$, $SD=2.14$). No other significant differences in valence or arousal ratings for women or men were found.

7.4.3. Electrophysiological Data

The grand mean average waveform at analysed sites for responses to each Valence category for women and men during the single and dual conditions is depicted in Figure 2

Table 2

The Sex-specific Mean Valence and Arousal Ratings of the Presented Image Categories as provided by the IAPS Collection and as Rated by Study Participants

Variable	Condition	IAPS		Participants				
		Women	Men	Women	Men	*F*	*p*	ηp^2
Valence	Neutral	5.69 (.90)	5.55 (.75)	5.30 (.50)	5.23 (.48)	.04	.84	.001
	Pleasant	5.87 (1.19)	6.47 (1.30)	6.22 (.66)	6.15 (1.54)	2.28	.14	.057
	Unpleasant	2.19 (.90)	3.03 (1.06)	2.30 (.93)	2.31 (.91)	.01	.95	<.001
Arousal	Neutral	3.50 (.86)	3.40 (.87)	2.86 (1.55)	1.98 (.89)	.04	.84	.001
	Pleasant	5.53 (.97)	5.74 (1.56)	5.24 (.86)	5.29 (1.77)	1.54	.22	.039
	Unpleasant	6.65 (.60)	6.01 (.62)	5.05 (.88)	3.79 (.41)	4.08	.050	.097

Note. Standard Deviations in parentheses; Univariate ANOVA results reported for ‘participant’ data; IAPS = International Affective Picture System (Lang, Bradley, & Cuthbert, 2008)

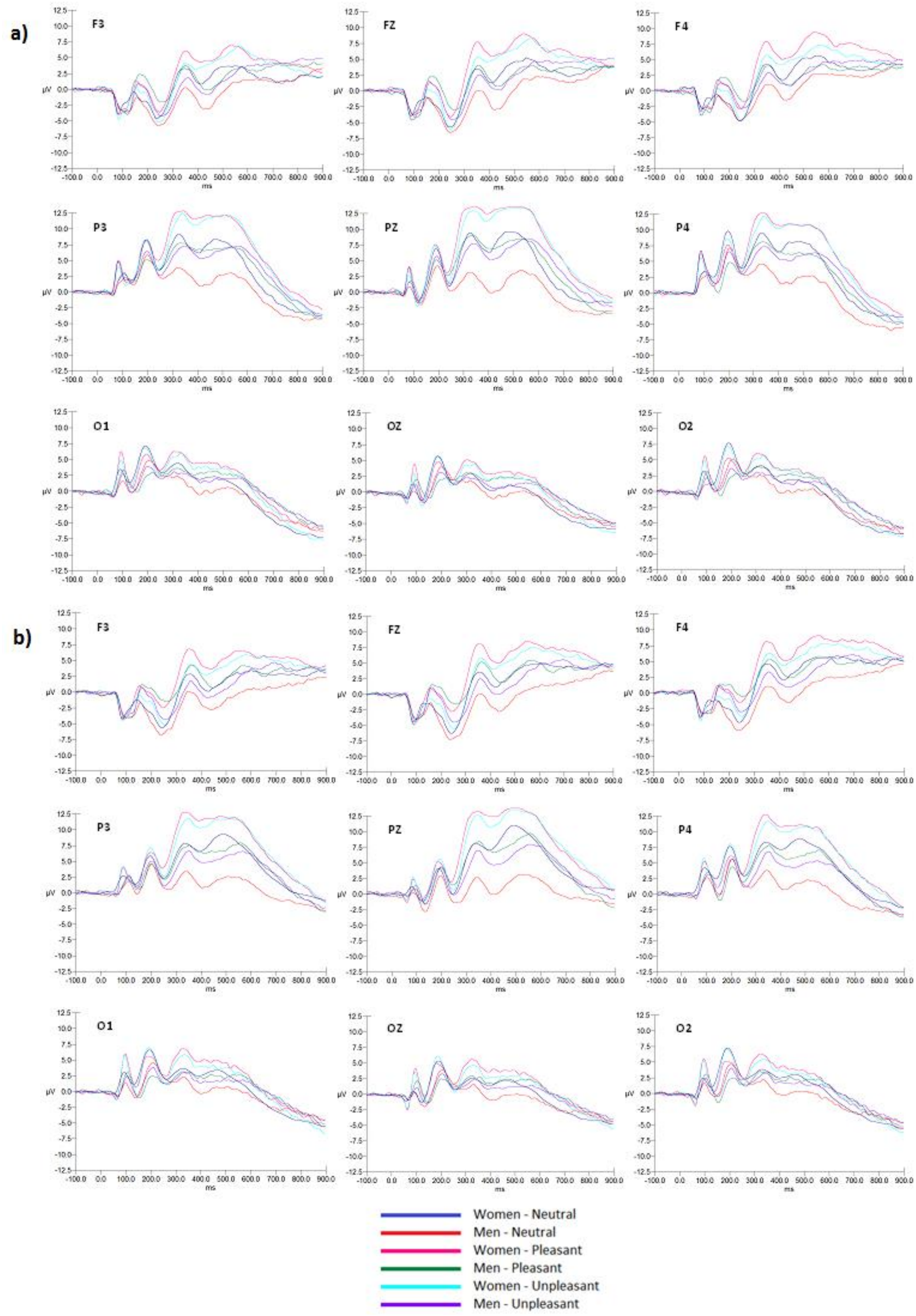

Figure 2. Grand mean average waveform of valence categories for women and men during the a) single and b) dual conditions.

7.4.3.1. Early Processing: P1

A significant main effect of Valence was revealed for the P1 peak amplitude data, $F(1.41, 53.50)=7.35$, $MSE=10.62$, $p=.004$, $\eta p^2=.162$, which demonstrated that P1 amplitude was significantly greater to the neutral stimuli relative to the pleasant ($p=.008$) and unpleasant ($p=.002$) stimuli, with no significant difference in P1 amplitude found between pleasant and unpleasant stimuli. No other significant main effects or interactions were observed for the P1 component.

7.4.3.2. Early Processing: N1

The N1 peak amplitude data revealed a trend towards a significant Sex × Valence interaction, $F(1.98,38)=2.91$, $MSE=99.20$, $p=.06$, $\eta p^2=.071$, however, Sidak post-hoc tests showed no significant differences between women and men at any valence, or between any valence for women or men. No other significant main effects or interactions were found for N1 amplitude.

7.4.3.3. Mid-latency Processing: N2

The N2 peak amplitude data revealed a significant main effect of Valence, $F(1.54, 58.34)=40.47$, $MSE=19.28$, $p<.001$, $\eta p^2=.516$, which showed that N2 amplitude was significantly higher to neutral relative to pleasant and unpleasant stimuli, with unpleasant stimuli higher than pleasant stimuli ($ps<.001$). This Valence main effect was superseded by a significant higher order Sex × Valence interaction, $F(1.54, 38)=4.56$, $MSE=321.85$, $p=.02$, $\eta p^2=.107$ (see Figure 3). Sidak post-hoc tests by Sex showed no significant differences. However, sidak post-hoc tests by Valence demonstrated that N2 amplitude for women was significantly higher to neutral ($p=.002$) and unpleasant (p=.001) compared with pleasant stimuli, with no significant difference between neutral and unpleasant stimuli observed. For men, N2 amplitude for neutral was significantly higher than both pleasant (p<.001) and unpleasant (p=.001), with N2 amplitude also shown to be significantly higher to unpleasant compared to pleasant stimuli (p=.002).

A significant Condition × Valence interaction, F(1.93, 73.45)=4.34, MSE=6.81, p=.02, ηp^2=.10, was also found. Sidak post-hoc tests by Condition showed that N2 amplitude was significantly higher during the single emotion processing relative to dual-oddball condition for pleasant stimuli, with no significant differences across conditions revealed for neutral or unpleasant stimuli. Sidak post-hoc tests by Valence demonstrated that N2 amplitude was significantly higher to neutral (p<.001) and unpleasant (p=.001) compared with pleasant stimuli, with no significant difference between neutral and unpleasant stimuli during the single emotion processing condition. During the dual-oddball condition, N2 amplitude for neutral stimuli was significantly higher than both pleasant (p<.001) and unpleasant (p=.001) stimuli, with N2 amplitude also shown to be significantly higher to unpleasant compared to pleasant stimuli (p=.001). No other significant main effects or interactions were found for the N2 component, including no significant Sex × Condition × Valence interaction, and the results did not suggest an impact of sex differences on task conditions.

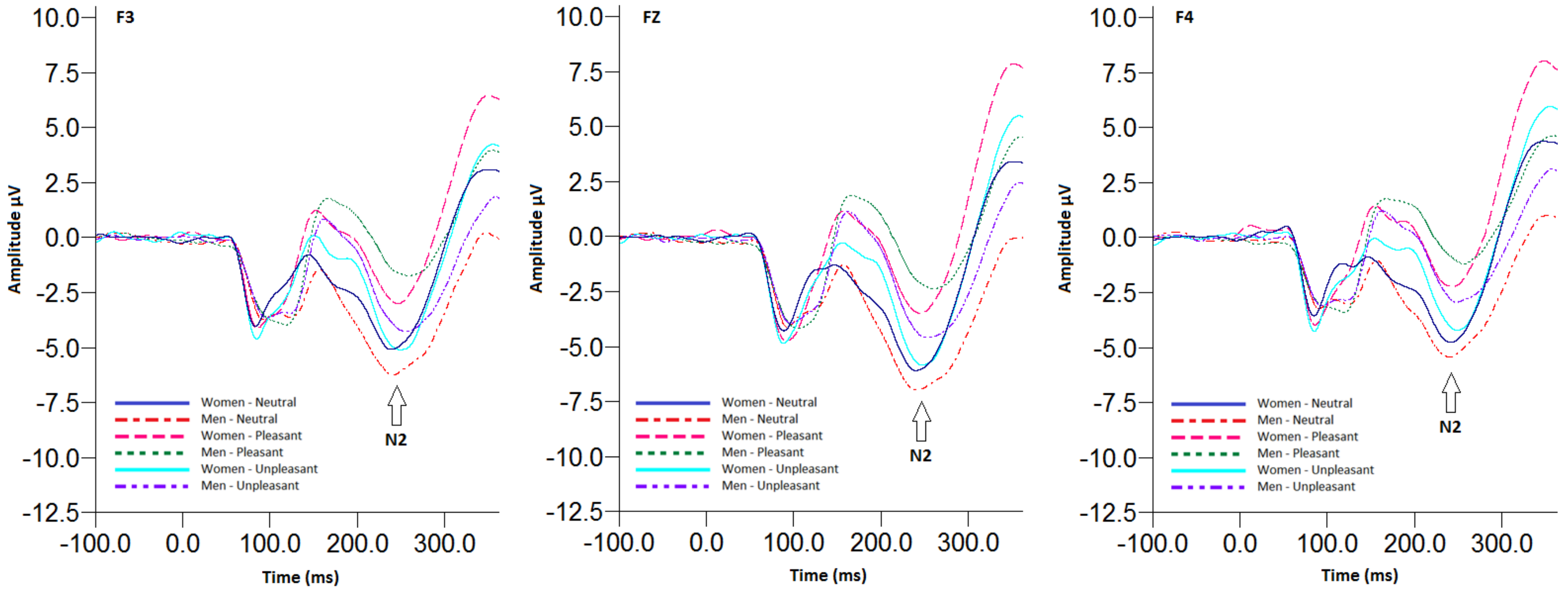

Figure 3. The Sex × Valence interaction for N2 amplitude at F3, FZ, and F4 sites collapsed across the single and dual conditions.

7.4.3.4. Late Processing: P3

A significant main effect of Sex, $F(1, 38)=24.84$, $MSE=231.94$, $p<.001$, $\eta p^2=.395$, was found for P3 amplitude which showed women to have significantly higher P3 amplitude relative to men. A significant Valence main effect was also found, $F(1.98, 75.07)=115.38$, $MSE=11.96$, $p<.001$, $\eta p^2=.752$, demonstrating that P3 amplitude was significantly higher to the pleasant relative to unpleasant and neutral stimuli, with unpleasant stimuli shown to elicit greater P3 amplitude that neutral stimuli (*ps*<.001). This Valence main effect was modified by a significant Condition × Valence × Site interaction, $F(2.81, 38)=2.68$, $MSE=231.94$, $p=.05$, $\eta p^2=.066$ (see Figure 4). Breakdown analyses were conducted to investigate this three-way interaction.

A Condition × Valence repeated-measures ANOVA at each Site was conducted and a main effect of Valence was found at P3, $F(1.98, 77.89)=104.14$, $MSE=4.10$, $p<.001$, $\eta p^2=.728$, PZ, $F(1.83, 71.47)=117.73$, $MSE=6.16$, $p<.001$, $\eta p^2=.751$, and P4, $F(1.95, 76.12)=71.47$, $MSE=4.40$, $p<.001$, $\eta p^2=.647$, sites. Sidak post-hoc tests revealed that irrespective of task condition, P3 amplitude at P3, PZ, and P4 sites was significantly greater to pleasant compared with neutral and unpleasant stimuli, with unpleasant stimuli also shown to be significantly greater than neutral stimuli (*ps*<.01).

A Valence × Site repeated-measures ANOVA for each task condition showed a main effect of Valence for both the single, $F(1.78, 69.34)=71.23$, $MSE=11.21$, $p<.001$, $\eta p^2=.646$, and dual, $F(1.93, 75.28)=77.24$, $MSE=8.77$, $p<.001$, $\eta p^2=.664$, conditions which demonstrated that P3 amplitude was significantly greater to pleasant compared with neutral and unpleasant stimuli, with unpleasant stimuli significantly greater than neutral stimuli during both conditions (*ps*$<.002$).

Similarly, a Valence × Site interaction was revealed for both the single, $F(3.55, 138.46)=16.78$, $MSE=.82$, $p<.001$, $\eta p^2=.301$, and dual, $F(2.53, 98.69)=5.74$, $MSE=2.0$, $p=.002$, $\eta p^2=.128$, conditions. Sidak post-hoc tests by Valence revealed that, irrespective of task condition, P3 amplitude at P3, PZ, and P4 sites was significantly greater to pleasant compared with neutral and unpleasant stimuli, with unpleasant stimuli also shown to be significantly greater than neutral stimuli at all sites except P4 during the dual condition (*ps*$<.03$). During both the single and dual conditions, sidak post-hoc tests by Site demonstrated that P3 amplitude to pleasant stimuli was significantly greater at PZ relative to P3 and P4 sites (*ps*$<.03$), whereas P3 amplitude to unpleasant stimuli was greater at PZ compared with P3 site during the single ($p<.02$) and dual ($p<.05$) conditions. No significant findings were demonstrated by a Condition × Site repeated measures ANOVA at each Valence level. No further significant main effects or interactions were demonstrated for P3 amplitude.

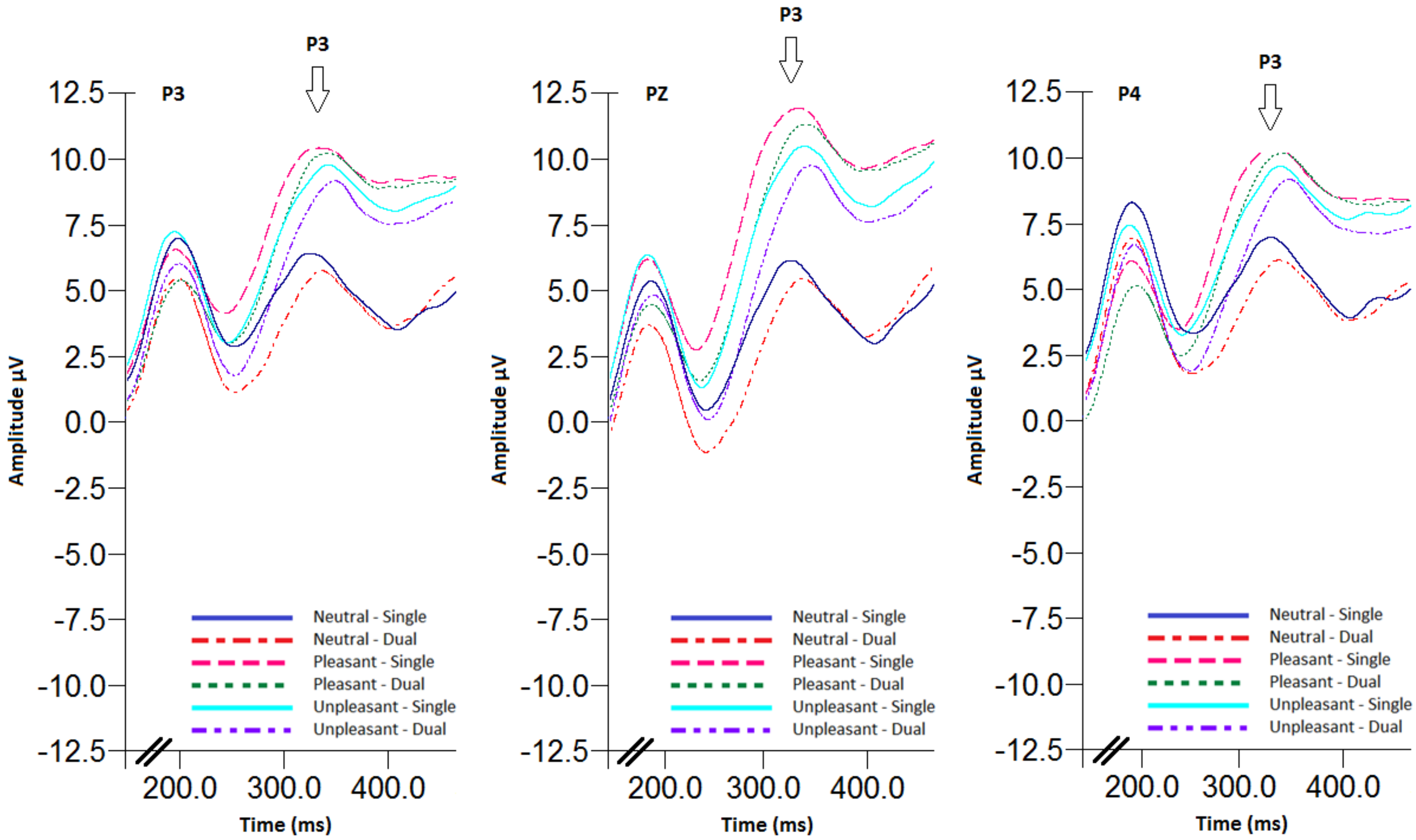

Figure 4. The Condition × Valence × Site interaction for P3 amplitude at P3, PZ, and P4 sites collapsed across women and men.

7.4.3.5. Late Processing: LPP

The LPP mean amplitude data revealed a significant main effect of Sex, *F*(1, 38)=14.86, *MSE*=183.79, *p*<.001, ηp^2=.281, indicating that women had significantly LPP amplitude overall than men (*p*<.001). A significant Condition main effect, *F*(1, 38)=5.28, *MSE*=40.65, *p*=.03, ηp^2=.122, demonstrated showed LPP amplitude to be significantly greater during the dual as compared with single condition (*p*=.03). Further, a significant main effect of Valence, *F*(1.96, 74.35)=155.12, *MSE*=8.76, *p*<.001, ηp^2=.803, showed that LPP amplitude was significantly greater to both pleasant and unpleasant relative to neutral stimuli (*ps*<.001), with no significant difference between pleasant and unpleasant stimuli observed. However, these findings were qualified by a trend towards a significant Sex × Condition × Valence interaction, *F*(2, 38)=2.85, *MSE*=183.79, *p*=.06, ηp^2=.07 (see Figure 5). To investigate this three-way interaction, a series of breakdown analyses were conducted.

A Sex × Valence interaction at each level of Condition produced significant main effects of Sex showing LPP to be significantly higher for women compared to men during the single, *F*(1, 38)=7.64, *MSE*=44.32, *p*=.009, ηp^2=.17, and dual, *F*(1, 38)=19.33, *MSE*=30.49, *p*<.001, ηp^2=.34, conditions. Significant main effects of Valence were also found and showed that LPP amplitude was significantly higher to the pleasant and unpleasant relative to neutral stimuli during the single, *F*(1.78, 67.66)=94.46, *MSE*=2.97, *p*<.001, ηp^2=.71, and dual, *F*(1.85, 70.16)=101.27, *MSE*=2.11, *p*<.001, ηp^2=.73, conditions. A significant Sex × Valence interaction, *F*(1.85, 1)=3.84, *MSE*=30.49, *p*=.03, ηp^2=.09 was also found during the dual condition.

Breakdown of this two-way interaction by Sex showed that women displayed significantly greater LPP amplitude than men to the pleasant (p=.001), unpleasant (p=.001), and neutral (p<.001) stimuli whereas sidak post-hoc tests by Valence showed that LPP amplitude was significantly greater to pleasant and unpleasant compared to neutral stimuli for both women and men (ps<.001).

A Condition × Valence interaction at each level of Sex revealed main effects of Valence for both women, $F(1.87, 35.46)=60.69$, MSE=3.4, $p<.001$, $\eta p^2=.76$, and men, $F(1.98, 37.59)=99.70$, MSE=2.57, $p<.001$, $\eta p^2=.84$, with each showing LPP amplitude to be significantly higher to the pleasant and unpleasant compared with neutral stimuli (ps<.001). A main effect of Condition, $F(1, 19)=4.85$, MSE=16.42, $p=.04$, $\eta p^2=.20$, showing LPP amplitude to be greater during the dual relative to single condition was also found for women (p=.04).

A Sex × Condition interaction at each level of Valence revealed significant main effects of Sex showing that LPP amplitude was significantly greater for women relative to men for the pleasant, $F(1, 38)=10.98$, MSE=22.70, $p=.02$, $\eta p^2=.22$, neutral, $F(1, 38)=19.91$, MSE=18.29, $p<.001$, $\eta p^2=.34$, and unpleasant, $F(1, 38)=11.64$, MSE=25.99, $p=.02$, $\eta p^2=.24$, stimuli. Significant main effects of Condition were demonstrated for the pleasant, $F(1, 38)=5.64$, MSE=6.12, $p=.02$, $\eta p^2=.13$, and neutral, $F(1, 38)=6.99$, MSE=5.71, $p=.01$, $\eta p^2=.16$, stimuli with each indicating that LPP amplitude was significantly higher during the dual relative to single conditions. A trend towards a significant Sex × Condition interaction was also found for neutral stimuli, $F(1, 38)=3.92$, MSE=5.71, $p=.055$, $\eta p^2=.093$. Sidak post-hoc tests by

Sex showed that women had significantly higher LPP amplitude than men during both the single (p=.009) and dual (p<.001) conditions, whereas post-hoc tests by Condition demonstrated that LPP amplitude was significantly greater during the dual relative to single condition for women (p=.002). No other main effects or interactions reached significance for the LPP component.

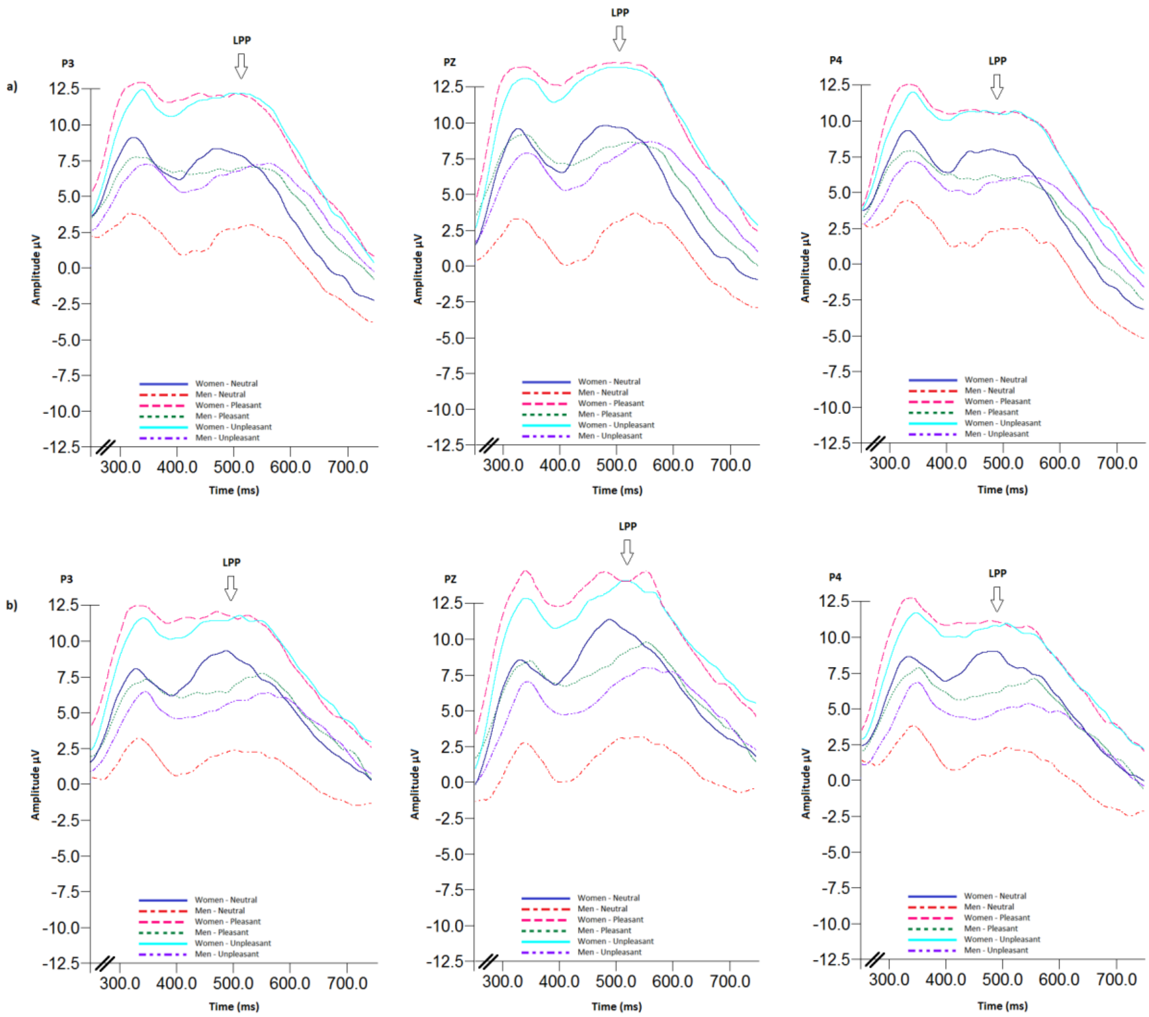

Figure 5. The Sex × Condition × Valence interaction for LPP amplitude at P3, PZ, and P4 sites during the a) single and b) dual conditions.

7.5. Discussion

This study investigated sex differences to emotional stimuli, with the specific aim to test whether there was a negativity bias in women, reflected by greater ERP amplitudes to unpleasant stimuli, or whether women display more generalised cortical reactivity to pleasant and unpleasant relative to neutral stimuli in line with the motivational model. Providing support for the negativity bias hypothesis, women reported greater arousal ratings to unpleasant stimuli than men, however, no evidence for the negativity bias hypothesis was demonstrated in cortical ERP processing for either women or men. While no evidence for the motivational model was demonstrated in early (P1, N1) or mid-latency (N2) ERP components, support was revealed during late conscious processing. P3 and LPP amplitudes were greater to pleasant and unpleasant compared with neutral stimuli during both the single and dual-task conditions. However, there were no sex differences in relation to the motivational model as this effect was observed across the sexes. Further, during the dual condition, women were shown to have significantly greater LPP amplitude than men to all valences. An unexpected finding was demonstrated for the N2 component as women displayed greater N2 amplitude to neutral and unpleasant stimuli relative to pleasant stimuli, while men showed greater N2 amplitude to neutral compared to both unpleasant and pleasant stimuli, with unpleasant stimuli shown to be higher than pleasant stimuli.

When considered together the results of this study were divergent to previous research given that we did not provide evidence for the negativity bias, and while some support for the motivational model during late processing was obtained, this support did not reflect the pattern of responses typically reported of greater emotional responsivity in women relative to men (e.g., Bradley et al., 2001b; Cuthbert et al., 2000; Ito & Cacioppo, 2005; Schupp et al., 2000). Hence, the observed processing differences between women and men in the current study did not support either the negativity bias or motivational explanations of emotion processing.

7.5.1. Negativity Bias Hypothesis

Women in the current study reported greater arousal ratings to unpleasant images than men. This behavioural data confirms previous studies which have reported greater distress or arousal to negative images in women relative to men (e.g., Bradley et al., 2001; Kring & Gordon, 1998). However, we did not find ERP evidence of a negativity bias as hypothesised, as there was no evidence of greater amplitudes in any ERP component to unpleasant emotional stimuli in women compared to men. This finding contradicts some recent ERP studies which have reported data consistent with a negativity bias in women as N1 and N2 component amplitudes were shown to be increased to unpleasant emotional images compared to neutral images in women but not in men (e.g., Gardener et al., 2013; Li et al., 2008; Lithari et al., 2010).

This failure to find a negativity bias may relate to the type of task employed. Recent studies reporting robust negativity biases in women have used passive viewing tasks (Gardener et al., 2013; Lithari et al., 2010), whereas the present study used an emotional categorisation task presented in a counterbalanced order with a dual-task condition in which a visual oddball task was presented concurrently with the emotional images. This design may have led to generally depleted cognitive resources compared to a standard passive viewing task and may have consequently blunted attentional effects observed in early ERP components (Pratt, Willoughy, & Swick, 2011).

The nature of the experimental stimuli may also have impacted the obtained findings. While the interaction of valence and arousal factors on emotion processing is largely unknown (Feng et al., 2014), valence and arousal are considered primary dimensions of emotional stimuli, and this study did not carefully balance the arousal and valence factors of the stimuli. Further, the pleasant stimulus category was comprised of mainly sexually erotic stimuli which are known to increase arousal and ERP component amplitudes, and this inclusion of erotic stimuli may thus have minimised potential negativity bias effects that are more evident in studies which have not included erotic stimuli (e.g., Lithari et al., 2010). Thus, it is probable that using highly arousing pleasant images in the experimental task minimised potential condition effects and discrimination from unpleasant arousing images. Future research should therefore further investigate the theoretical questions posed in this study using a pure passive viewing task containing stimuli that have been well balanced in valence and arousal elements to allow the un-confounded cortical processing of emotional stimuli to be measured.

7.5.2. Motivational Model

While no evidence for the motivational model was demonstrated in early (P1, N1) or mid-latency (N2) ERP components, some support was demonstrated during late conscious processing. The motivational model predicts that there will be greater processing of both pleasant and unpleasant compared to neutral stimuli (Cuthbert et al., 2000; Schupp et al., 2003; Schupp et al., 2004). This effect was largely confirmed for later cortical processes in this study, as P3 and LPP amplitudes were greater to pleasant and unpleasant compared with neutral stimuli irrespective of sex during both the single and dual-task conditions. A sex difference was revealed during the dual-task condition as LPP amplitude was greater to pleasant and unpleasant relative to neutral stimuli for women and men, with women shown to have significantly greater LPP amplitude than men to all valences. However, the observed sex effect in LPP during the dual-task condition does not provide support for the motivational model as this generalised increase in LPP amplitude in women was not valence specific. Rather, this result is reflective of women having greater late conscious processing relative to men in general, in line with studies which have reported greater LPP amplitudes irrespective of valence (e.g., Glaser, Mendrek, Germain, Lakis, & Lavoie, 2012; Rozenkrants & Polich, 2008; Weinberg, Hilgard, Bartholow, & Hajcak, 2012). Further, these valence effects were observed regardless of site, which differs from previous ERP studies in which evidence of greater P3 amplitudes to emotional stimuli has been found in the left hemisphere for women, and in the right hemisphere for men (Gasbarri et al., 2006, 2007).

Whilst the behavioural ratings data did support a negativity bias in women, which replicates many previous studies, when the obtained ERP data is considered together with the two theoretical models underpinning this study, it is clear that our prediction of greater cortical reactivity to unpleasant than pleasant or neutral stimuli in women compared to men has not been supported by the obtained results, as we found no evidence of a female negativity bias for any ERP component. Similarly, our prediction in line with the motivational model that cortical processing of emotional (pleasant and unpleasant) relative to neutral stimuli would be greater for women as compared to men was also not supported as we did not reveal any evidence of women displaying greater amplitudes than men to emotional relative to neutral stimuli for any ERP component. As noted above, the current findings are divergent from previous findings, and this may relate to some key methodological variables.

The majority of pleasant stimuli used in the present study were sexually erotic stimuli with three quarters of pleasant images comprising erotic men, erotic women, or erotic couples. As valence is thought to influence earlier ERP components, and arousal later ERP components (Gianotti et al., 2008), it is possible that the finding of increased P3 and LPP amplitudes to the pleasant stimuli is due to increased arousal levels exhibited in response to the erotic images. However, the finding of greater LPP amplitude to highly arousing erotic stimuli in women contrasts with previous evidence of increased processing of, and greater LPP amplitude to, erotic stimuli in men rather than women (Allen et al., 1997; Bianchin & Angrilli, 2012; Bradley et al., 2001; Sabatinelli et al., 2004). Alternatively, the LPP finding may be interpreted in line with women having a more complex approach to perceiving sexual stimuli that focuses not only on sexual aspects of a stimulus (as men have been found to do), but also on nonsexual and contextual factors (Rupp & Wallen, 2007). This interpretation is consistent with arguments that LPP indexes the degree (i.e., timing and level) of evaluative processing required for response evaluation (e.g., Cacioppo et al., 1996; Fabiani et al., 2000; Purves et al., 2008) in that women showed greater evaluative processing than men when viewing pleasant stimuli. Furthermore, LPP amplitude has been shown to be higher to erotica images than to other emotional categories in women during their ovulatory (high estradiol) menstrual cycle phase (Krug et al., 2000). As the majority of pleasant images in the current study were sexually graphic and menstrual cycle effects were not measured, potentially confounding effects of menstrual phase on the obtained findings should be considered as it is probable that a large number of women in our female sample were in the high estradiol phase of their menstrual cycle.

As noted above, the valence and arousal dimensions of stimuli in the current study were not carefully balanced and this may have implications for LPP responses, in addition to earlier attentional processing. Whilst some previous studies have balanced valence and arousal, it is noteworthy that these studies have reported inconsistent findings regarding the influence of valence and arousal factors on the processing of emotional stimuli. More specifically some studies have not observed a valence by arousal interaction on either early (e.g., P1) or late (e.g., LPP) ERP components, but did demonstrate separate effects of valence and arousal (e.g., Lithari et al., 2010; Rozenkrants & Polich, 2008). Alternatively, other studies have reported valence by arousal interaction modulation of both early and late ERP components (e.g., Feng et al., 2012a). As previous research has demonstrated that arousal influences valence effects on emotional picture processing at both behavioural and cortical levels (e.g., Nielen et al., 2009), arousal may have had a modulatory influence on potential valence effects in the current study. This suggestion is consistent with Cacioppo and Bernston (1994) who proposed that the aversive system typically responds more strongly than the appetitive system when the arousal level of emotional stimuli is high (negativity bias), whereas the opposite is observed when the arousal level if low (positive offset). It is thus unknown whether pleasant stimuli evoked either higher or lower cortical responses compared with unpleasant stimuli, as the arousal level of the experimental stimuli were not controlled. The failure to not adequately balance arousal and valence may thus have impacted on stimuli discriminability and reduced the likelihood of observing a negativity bias or conclusive evidence for the motivational model. Furthermore, it is possible that using highly arousing pleasant and unpleasant stimuli may have led to generalised increases in arousal, leading to enhanced processing of all stimuli whether emotional (pleasant or unpleasant) or neutral.

In addition, many prior studies in this field have used passive viewing paradigms, and it is conceivable that the inclusion of the dual-task may have reduced responsivity and processing of the pleasant stimuli, possibly more in men given that men in the current study did not exhibit greater processing of erotic stimuli as has consistently been formerly demonstrated (e.g., Allen et al., 1997; Bianchin & Angrilli, 2012; Bradley et al., 2001; Sabatinelli et al., 2004). The nature of the emotion categorisation task may thus have interfered with natural emotion processing mechanisms. Subsequent studies should therefore explicitly control for the valence and arousal of stimuli and employ a pure passive viewing task to allow natural emotion processing to be measured.

7.5.3. Early Conscious Attention: N2

The current findings did not demonstrate any sex differences in P1 or N1 amplitude, however, an unusual finding was demonstrated for the N2 component. Women displayed greater N2 amplitude to neutral and unpleasant relative to pleasant stimuli. Similarly, men exhibited greater N2 amplitude to neutral compared with both unpleasant and pleasant stimuli, with unpleasant stimuli also shown to be significantly greater than pleasant stimuli. These findings are opposite to predictions of both the motivational model and the negativity bias hypothesis. Previous literature generally reveals reduced N2 amplitude to neutral compared to emotive stimuli in both women and men (e.g., Kemp et al., 2004; Lithari et al., 2010; Sass et al., 2010; Whittle et al., 2011). Very little research has examined sex differences to neutral stimuli on their own as neutral stimuli are typically used as baseline stimuli rather than experimental stimuli of interest. Consequently, it is premature to interpret this N2 finding in response to neutral stimuli as this result requires replication and further exploration. In affective paradigms, N2 is thought to reflect attention towards salient, emotionally arousing stimuli selected for further processing (Oloffson et al., 2008; Schupp et al., 2006). Taken together, the N2 findings suggest that neutral stimuli evoked greater selective attention resources (greater N2 amplitude) in women and men whereas the pleasant stimuli evoked fewer attentional resources for women and men.

While neither sex differences in mood or in valence ratings were observed in the current study, recent evidence suggests that N2 ERP responses are modulated by mood and other individual differences variables (e.g., Campanella et al., 2012). Future research should therefore investigate cortical reactivity, emotion processing style, traits, emotion regulation, and mood more precisely in conjunction with emotional and neutral ERPs.

7.5.4. Limitations and Future Research

The present study had several limitations which may have led to divergent findings from previous research. The use of the dual-task may have confounded cortical responses to the emotional stimuli. To avoid potential confounds of emotion and superimposed cognitive processing a passive viewing task can be used to investigate un-confounded emotion processing. The passive viewing task is a commonly used paradigm which has been used in both early (see Olofsson et al., 2008) and more recent studies (e.g., de Rover et al., 2012; Ferrari Bradley, Codispoti, Karlsson, & Lang, 2013; Gardener et al., 2013; Leite et al., 2013; Lithari et al., 2010; Wheaton et al., 2013). In addition, a review assessing 40 years of prior emotion ERP studies demonstrated that similar ERP emotional findings have been found across different research paradigms including passive viewing, active discrimination, categorisation, and speeded response tasks, thus indicating that the passive viewing task paradigm is a valid method for investigating the processing of emotional information (Oloffson et al., 2008). Future research could therefore utilise a passive viewing task methodology to examine the question of whether women's cortical processing of emotional stimuli supports the negativity bias hypothesis or the motivational model of emotion processing.

A further limitation of this study and of much previous electrophysiological research is the failure to control for the effect of menstrual phase on emotion processing. The powerful influence of menstrual phase on emotional processing is increasingly being documented (e.g., Felmingham et al., 2012; Krug et al., 2000; Toffoletto et al., 2014). Recent neuroimaging emotion studies have reported substantial menstrual cycle modulation of the limbic network, identified as the structures in the brain responsible for the control of emotion, with such modulation impacting emotion processing. For example, Andreano & Cahill (2010) have recently reported fMRI evidence that the midluteal phase enhances limbic processing of emotional stimuli. Hence, the growing evidence regarding the impact of sex hormones on the cortical processing of emotion necessitates the need for menstrual cycle effects on ERPs and emotion to be considered in future research using tasks which balance the valence and arousal of stimuli and which do not contain sexual stimuli to allow the un-confounded impact of menstrual phase on emotion processing to be investigated.

7.5.5. Conclusion

The current study examined the cortical processing of emotional images in women and men to test competing hypotheses regarding sex differences in emotional processing. Our hypotheses were not confirmed by the current findings. While no evidence for the negativity bias hypothesis was observed, there was some evidence for the motivational model during late cortical processing. However, sex differences were not seen in this motivational effect on later processing, as whilst P3 and LPP amplitude were greater in women than men, this was generalised across all stimuli (including neutral), which does not fit with motivational model predictions. Overall, the findings are unclear, did not provide definitive support for the motivational model, and are divergent to previous research findings. This failure to confirm previous studies may have resulted from several methodological factors such as the use of a dual-task, failure to balance the valence and arousal dimensions of stimuli, inclusion of sexually erotic stimuli, and failure to consider the impact of sex hormones on the processing of emotional information. Future research should utilise a pure passive viewing task to examine sex differences in the processing of emotional stimuli whilst controlling for menstrual phase to further elucidate these models of emotion processing.

7.6. Acknowledgements

We wish to thank Dr Michael Quinn for assistance with data analysis. We also thank participants for their contribution to this study.

7.7. Implications for the Program of Research

The aim of Study 1 was to examine sex differences in ERP responses to neutral, pleasant, and unpleasant visual stimuli to investigate whether women display greater processing of unpleasant stimuli specifically, in line with the negativity bias hypothesis, or of emotional stimuli in general, as outlined by the motivational model. Although some behavioural evidence in support of the negativity bias was found, no ERP evidence for the negativity bias hypothesis was revealed. Some evidence for the motivational model during late cortical processing was demonstrated for both women and men. Considered together however, the results of Study 1 were unclear, did not provide compelling support for the motivational model, and were divergent to previous research. These discrepancies and failure to support hypotheses may have related to the methodological issues discussed in Study 1, namely the use of a dual-task paradigm, the failure to balance arousal and valence, the inclusion of sexual stimuli, and the failure to control for menstrual phase. Study 2 tested whether there was a negativity bias or evidence for generalised emotional processing (motivational model) in women compared to men in a passive viewing task, with stimuli balanced for valence and arousal (and no sexual stimuli included), whilst controlling for menstrual phase. Hence, Study 2 addressed a gap in the current literature by using high temporal resolution ERPs to investigate whether menstrual phase is associated with the negativity bias or motivational model by comparing the cortical processing of visual emotional stimuli for early follicular women, midluteal women, and men.

CHAPTER 8: EARLY VISUAL PROCESSING IS ENHANCED IN THE MIDLUTEAL PHASE OF THE MENSTRUAL CYCLE

Early Visual Processing is Enhanced in the Midluteal Phase of the Menstrual Cycle

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8.1. Abstract

Event-related potential (ERP) studies have revealed an early attentional bias in processing unpleasant emotional images in women. Recent neuroimaging data suggests there are significant differences in cortical emotional processing according to menstrual phase. This study examined the impact of menstrual phase on visual emotional processing in women compared to men. ERPs were recorded from 28 early follicular women, 29 midluteal women, and 27 men while they completed a passive viewing task containing neutral and low- and high- arousing pleasant and unpleasant images. There was a significant effect of menstrual phase in early visual processing, as midluteal women displayed significantly greater P1 amplitude at occipital regions to all visual images compared to men. Midluteal women also displayed larger N1 amplitudes than men to the visual images. No sex or menstrual phase differences were apparent in later N2, P3, or LPP. A condition effect demonstrated greater P3 and LPP amplitude to highly-arousing unpleasant images relative to all other stimuli conditions. These results indicate that women have greater early automatic visual processing compared to men, and suggests that this effect is particularly strong in women in the midluteal phase at the earliest stage of visual attention processing. Our findings highlight the importance of considering menstrual phase when examining sex differences in the cortical processing of visual stimuli.

8.2. Introduction

Large-scale epidemiological studies consistently reveal that women develop anxiety disorders and depression at twice the rate of men (Australian Bureau of Statistics, 2007, 2015; Kessler et al., 1994, 2005; McLean et al., 2011). Despite this prevalence, the mechanisms underlying this female vulnerability remain unknown. One possibility is that women display greater affective reactivity than men, specifically to unpleasant/threatening stimuli, reflecting a negativity bias (Gardener et al., 2013; Li et al., 2008; Lithari et al., 2010; Stevens & Hamann, 2012). The negativity bias hypothesis predicts greater reactivity to unpleasant compared to pleasant and neutral stimuli (Ito & Cacioppo, 2005). Accordingly, previous behavioural studies have shown that men have greater reactivity to high arousing pleasant stimuli (erotica) than women (Allen et al., 2007; Sabatinelli et al., 2004), whilst women have been shown to have faster reaction times and higher accuracy to emotive (predominantly unpleasant) stimuli relative to men (e.g., Li et al., 2008, Whittle et al., 2011), and greater self-reported arousal and distress ratings of unpleasant stimuli (e.g., Bradley et al., 2001b; Stevens & Hamann, 2012).

Event-related potential (ERP) studies provide further evidence for a negativity bias in women, with women showing increased N1 and N2 amplitudes to unpleasant emotional stimuli relative to men in passive viewing tasks (e.g., Gardener et al., 2013; Lithari et al., 2010). However, these studies failed to include a neutral baseline condition. Other studies have reported a negativity bias in women to unpleasant relative to neutral stimuli. In an oddball task, Li et al. (2008) reported that whilst both men and women displayed greater N2 and P3 amplitudes to highly unpleasant images, only women displayed increased N2 and P3 amplitudes to moderately unpleasant stimuli. Despite growing evidence regarding the influence of sex hormones on the cortical processing of emotion (e.g., Toffoletto et al., 2014), these studies demonstrating support for the negativity bias did not control for menstrual phase.

The failure to examine menstrual phase in relation to emotional processing is important, given recent neuroimaging studies revealing greater activation of limbic networks (amygdala and hippocampus) to emotionally arousing stimuli in women in the midluteal phase compared to women in the early follicular phase (Andreano & Cahill, 2010; Bayer et al., 2014; Gingnell et al., 2012). Further, van Wingen et al. (2008) found increased activity in the amygdala and the hippocampus, following an exogenous dose of progesterone, which matched levels observed naturally during the midluteal phase. Whilst highlighting the impact of the menstrual phase on neural processes, neuroimaging studies are limited as they do not allow delineation of precise temporal processes in the interaction between menstrual phase and the processing of visual emotional stimuli. High temporal resolution ERP methodology enables the investigation of sex differences in preconscious (automatic) and conscious neural indices of visual emotion processing. Although ERPs constitute a valuable research method, there are relatively few ERP studies that have examined menstrual phase modulation of visual emotion processing.

Only a handful of recent ERP studies have examined the impact of menstrual phase and these studies have reported inconsistent findings. Wu et al. (2014) investigated processing of neutral and moderately and highly unpleasant visual stimuli across mid-late luteal and mid-late follicular menstrual phases using an oddball paradigm. They showed that N2 amplitude was higher to both moderately and highly unpleasant stimuli relative to neutral stimuli in the mid-late luteal phase, whereas no difference was found during the mid-late follicular phase. This result supports the negativity bias in women, and suggests that the processing bias is particularly evident in midluteal women, which converges with recent neuroimaging results (e.g., Andreano & Cahill, 2010). However, due to the nature of the dual-task paradigm employed, whereby an attention oddball task was superimposed on an emotion perception task, it is difficult to differentiate the effects of menstrual phase on attention and emotion processes in this study. In comparison, Zhang et al. (2013) examined ERPs to facial expressions of emotion in the early follicular, late follicular, and mid-late luteal menstrual phases and reported increased late positive potential (LPP) amplitudes, which index later, conscious processing (Hajcak et al., 2010), to *all* facial expressions in the mid-late luteal phase compared to the early follicular and late follicular phases. *Such a finding raises the question of whether there is enhanced visual processing of all stimuli rather than a specific negativity bias to unpleasant stimuli in midluteal women.*

The potential for the midluteal phase to be associated with enhanced visual processing is consistent with recent research revealing a link between progesterone (which dominates the midluteal phase) and visual processing. Using the binocular rivalry paradigm to explore the influence of estradiol and progesterone in early follicular women, midluteal women, and men on mental visual imagery strength and memory of visual emotional stimuli, progesterone was shown to interact with visual processing leading to greater visual memory and reactivity to visual emotional stimuli (Wassell et al., 2015a) and enhanced visual imagery strength and vividness (Wassell et al., 2015b). This provides behavioural evidence of increased visual processing in midluteal women relative to early follicular women and relative to men.

To investigate whether the midluteal phase is associated with a negativity bias to unpleasant stimuli or enhanced visual processing overall, this study compared early follicular and midluteal women and men on the processing of visual emotional stimuli using ERPs. We examined the early follicular phase as an exemplar of both low estradiol and progesterone and the midluteal phase as an exemplar of high estradiol and progesterone (Nillni, Toufexis, & Rohan, 2011; Sacher, Okon-Singer, & Villringer, 2013). If the midluteal phase is associated with a negativity bias, we would predict increased ERP component amplitudes to unpleasant stimuli compared with pleasant and neutral stimuli in midluteal women compared with both early follicular women and men. In contrast, if the midluteal phase is associated with generally-enhanced visual processing, we would predict midluteal women to have increased ERP component amplitudes to all visual stimuli relative to early follicular women and men.

8.3. Method

8.3.1. Participants

Eighty four healthy, right handed, non-smoking Caucasian adults were recruited from first-year psychology undergraduates. Participants were 28 women in the early follicular (days 2-6; low estradiol/low progesterone) phase of their menstrual cycle (age range 18-44 years; *M*=23.54, *SD*=6.60), 29 women in the midluteal (days 18-24; high estradiol/high progesterone) phase of their menstrual cycle (age range 18-40 years; *M*=23.45, *SD*=7.51), and 27 men (age range 18-40 years; *M*=24.41, *SD*=7.16). Three women currently prescribed a combination contraceptive pill and tested on day 4 of their sugar pill while menstruating were included in the early follicular sample[2]. To ensure accuracy of menstrual phase allocation, women contacted the researcher on day one of their menses, and were tested in the early follicular phase when menstruating or were scheduled for testing during the midluteal phase, calculated from their first day of menstruation[3]. Women were deemed ineligible for this study if they were pregnant or possibly pregnant, had been pregnant or had given birth during the previous 12 months, reported a typical monthly menstrual cycle below 27 days or above 29 days, had currently or previously experienced abnormal or irregular menstrual cycles, menopause, or reported any type of abnormal hormonal condition. Participants who reported medication use, substance abuse or dependence, a history of neurological disorders, brain injury or loss of consciousness greater than five minutes, mood disturbance, or anxiety in response to the visual stimuli in the experimental task were excluded from this study. Participants gave written informed consent and this study had ethical approval from the Social Sciences HREC (University of Tasmania; UTAS).

[2] Analyses of all data sets were conducted with and without the three females on contraceptives (see Appendix F). Removal of these participants did not affect the findings and therefore the full early follicular sample is reported.

[3] No women were excluded due to progesterone levels being inconsistent with expected menstrual phase levels or due to anovulatory cycles.

8.3.2. Stimuli and Materials

8.3.2.1. Depression, Anxiety, Stress Scale

Completed prior to testing by participants, the 42-item self-report Depression, Anxiety, Stress Scale (DASS; Lovibond & Lovibond, 1995) was used to provide an estimate of participant's level of depressed, anxious, and stressed mood on the day of testing. Each item is measured on a four-point Likert scale (0 = *did not apply to me at all*, 3 = *applied to me very much, or most of the time*). Participants' DASS responding and the scale scoring were completed according to the standardised instructions and used to provide an estimate of participants' mood state. The DASS is a highly reliable measure of depression (α = .95), anxiety (α = .90), and stress (α = .93) (Lovibond & Lovibond).

8.3.2.2. Passive Viewing Task

A passive viewing task adapted from Lithari et al. (2010) presented International Affective Picture System (IAPS; Lang et al., 2008) images, which comprised five stimulus conditions of neutral, and low- and high-arousing pleasant and unpleasant images[4] (see Appendix J individual stimuli ratings of valence and arousal). Each condition contained 40 images to ensure good signal-to-noise ratios (20 images each presented twice). IAPS normative data were used to guide image selection: neutral valence rating was between

[4] IAPS images used in this experiment - Neutral: 1333, 2221, 2312, 2399, 2515, 2525, 2392, 5410, 5720, 5726, 5875, 7078, 7079, 7509, 8251, 8260, 9010, 9110, 9390, 9913; Low Arousing Pleasant: 1441, 1610, 2360, 2370, 2388, 2530, 5000, 5001, 5010, 5200, 5201, 5202, 5551, 5760, 5779, 5780, 5781, 5811, 5891, 7325; High Arousing Pleasant: 2347, 5470, 5621, 5629, 5833, 5910, 7405, 8030, 8034, 8080, 8163, 8170, 8185, 8186, 8190, 8200, 8370, 8490, 8492, 8501; Low Arousing Unpleasant: 2205, 2375.1, 2750, 2900.1, 3300, 6311, 9000, 9220, 9280, 9290, 9291, 9320, 9330, 9331, 9342, 9415, 9432, 9830, 9831, 9832; High Arousing Unpleasant: 3000, 3001, 3010, 3053, 3060, 3063, 3064, 3068, 3069, 3071, 3080, 3102, 3110, 3140, 3170, 3266, 3400, 9183, 9252, 9405.

‘4’ and ‘6.5’ (M=5.03) while neutral-arousal rating was between ‘4’ and ‘6’ (M=3.90); pleasant valence rating was between ‘7’ and ‘9’ (M=7.45) while unpleasant images had a valence rating between ‘1’ and ‘3’ (M=2.15); arousal ratings for both the pleasant and unpleasant stimuli were ‘4.5 and lower’ (M=3.97) and ‘5.5 and higher’ (M=6.63) for low-arousal and high-arousal respectively. The valence and arousal means for the neutral condition were significantly different to the other four conditions. The valence mean for each pleasant condition was significantly higher than the valence mean for the neutral condition and each unpleasant condition, and both low arousal conditions had significantly lower arousal means compared to the neutral condition and both high-arousal conditions. Planned linear coefficient contrasts demonstrated that both pleasant conditions were significantly more pleasant than both unpleasant conditions, $t(145.78)=-122.20$, $p<.001$, and both high-arousal conditions compared to both low-arousing conditions were significantly more arousing, $t(123.69)=43.56$, $p<.001$.

8.3.3. Salivary Estradiol and Progesterone

Salivary measures of baseline estradiol and progesterone levels were taken to enable confirmation of menstrual cycle states in women (Gandara et al., 2007). Participants refrained from consuming food, caffeine, and nicotine for three hours prior to the study, and avoided alcohol or excessive exercise for 24 hours prior to the study in order to control for potential confounds on hormonal or neural responses (e.g., Brot et al., 1995; Fabiani et al., 2000; Polich, 2007). Saliva samples were self-collected by participants in tubes, using the standard passive drool method (Shirtcliff et al., 2001), immediately frozen, and stored at -20^{o}C until assay. On analysis day, specimens were thawed and centrifuged at 1500×*g* for 15 minutes at room temperature. Estradiol and progesterone concentrations were determined by enzyme immunoassay with commercially available kits (Q-111 HS Salivary 17-ß Estradiol EIA and Q-112 Salivary Progesterone EIA kits; rabbit anti-estradiol/progesterone antibodies; Salimetrics, State College, Pennsylvania, USA) in the Pathology Laboratory in the Division of Pharmacy at UTAS, Tasmania, Australia. Estradiol data was not analysed since extremely low values in all participants suggested artefactual data.

8.3.4. Procedure

Participants attended the Cognitive Neuroscience Laboratory at UTAS for one two-hour testing session. Participants completed the DASS (Lovibond & Lovibond, 1995) and saliva samples were collected. Participants were prepared for EEG recording as described below and were seated in a sound-attenuated room to complete the passive viewing task, which contained a practice trial before experimental task presentation. Participants passively viewed the stimuli presented on the screen and were told that they would be asked questions regarding the stimuli (i.e., perceived valence/arousal) after the testing session, in order to ensure that they attended to the stimuli. The passive viewing task duration was approximately 16 minutes and images from all conditions were randomly intermixed and presented in a single task-block (see Figure 1). Following a fixation cross presented for 1000ms, each stimulus was presented for 1000ms with an inter-stimulus interval varying between 1600ms, 1700ms, 1800ms, 1900ms, and 2000ms. Following the passive viewing task, each stimulus was then independently rated for level of valence and arousal by participants on a 9-point Likert scale adapted from the IAPS normative data rating scale (Self-Assessment Manikin; Bradley & Lang, 1994): Valence (1 = *highly unpleasant*, 5 = *neutral*, 9 = *highly pleasant*); Arousal (1 = *not at all exciting/arousing*, 5 = *moderately arousing*, 9 = *highly exciting/arousing*).

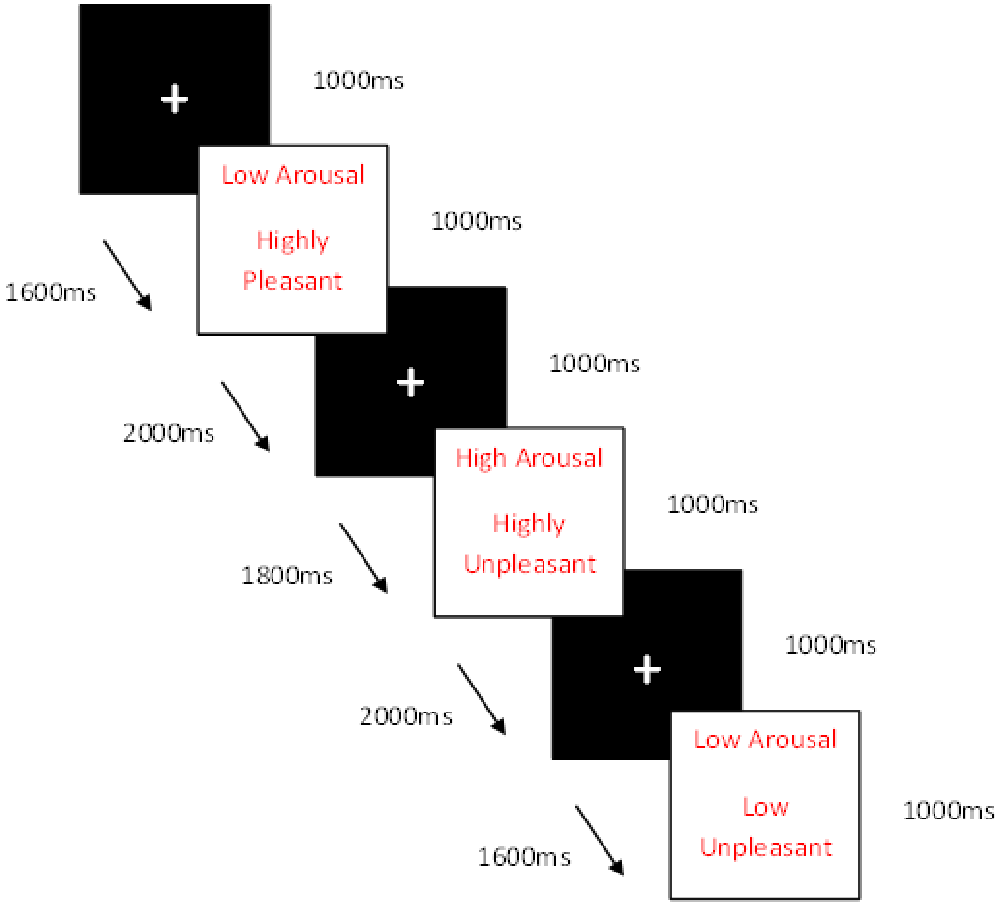

Figure 1. Flowchart of the passive viewing task stimulus presentation.

8.3.5. Electrophysiological Apparatus and Recording

EEG activity was recorded from 32 sites according to the international 10-20 system (Jasper, 1958) using a Quik-cap with silver/silver chloride (Ag/AgCl) electrodes and SynAmps 2 amplifiers. All electrode sites were referenced to linked mastoids and an AFz ground was used. Horizontal electro-oculographic (EOG) activity was recorded from electrodes placed at the outer canthi of both eyes, while vertical EOG activity was recorded from electrodes above and below the left eye. Electrode impedance was kept below 10KΩ and EEG data were sampled at 1000Hz and amplified with a high pass filter of 0.15Hz and a low pass filter of 100Hz. EEG data was merged with behavioural files followed by vertical and horizontal ocular artefact reduction. The ocular artefact reduction algorithm was developed by Compumedics Neuroscan (2006) and based on combined regression analysis and artefact averaging (Semlitsch et al., 1986). Continuous data files were then low-pass filtered at 30Hz at 48dB per octave, epoched offline for a 1000ms epoch commencing 100ms before stimulus onset, and baseline corrected. High and low voltage cut-offs for artefact rejections were set at 100µV and -100µV respectively. EEG activity corresponding to each stimulus condition was averaged and filtered with a high band pass of .15Hz and a low pass of 30Hz. In accordance with previous research and a visual inspection of grand means, N1 and N2 were defined as the peak negativities within 50-150ms and 200-350ms, respectively, over frontal electrodes (F3, FZ, F4; Hajcak et al., 2010). P1 was determined as the peak positivity within 60-120ms over occipital electrodes (O1, OZ, O2; Olofsson et al., 2008). P3 was measured as the peak positivity within the 250-450ms time window over parietal sites (P3, PZ, P4; O'Reilly et al., 2004). The LPP was determined as the mean positivity within 450-700ms over parietal sites (P3, PZ, P4; Krug et al., 2000). We limited our analyses to examining component amplitude rather than component latency, as a number of ERP components were examined and our hypotheses predicted differences in the magnitude rather than speed of cortical processing. Restricting analyses to amplitude effects only is consistent with a majority of recent ERP studies investigating emotion processing (e.g., Althaus et al., 2014; Galli et al., 2011; Groen et al., 2013; Jin, Yan, Zhang, Jiang, Tao, & Zheng, 2013; Lin et al., 2014; Luo et al., 2014; Meng et al., 2009; Pfabigan et al., 2014; Raz et al., 2014; Syrjänen & Wiens, 2013; Wiens & Syrjänen, 2013).

8.3.6. Design and Data Analysis

Separate univariate ANOVAs with Group as the between-subjects factor were conducted to assess any group differences in self-reported depressed mood, anxiety, and stress (as measured by the DASS) and in stimulus mean valence and arousal ratings for the neutral, and low- and high-arousing pleasant and unpleasant conditions (as measured by the picture rating task).

Peak amplitudes of P1, N1, N2, and P3 and the mean amplitude of the LPP were analysed using 3[Group: Early Follicular, Midluteal, Men] × 5(Condition: Neutral, Low-Arousing Pleasant, High-Arousing Pleasant, Low-Arousing Unpleasant, High-Arousing Unpleasant) × 3(Site: F3, FZ, F4 *or* P3, PZ, P4, *or* O1, OZ, O2) mixed factorial ANOVAs[5].

Artefactual (e.g., evidence of visual or physiological artefact) electrode channel data values were replaced with the mean score of the surrounding electrodes (Picton et al., 2000). Three electrode channels (FT7, FT8, FP2) were classified as artefactual for all participants, but these were not

[5] This study replicated the analysis procedure of Lithari et al. (2010) who examined Sex × Valence × Arousal × Site. However, given a lack of main effects, or interactions between valence and arousal,
valence and arousal variables were collapsed into ‘stimulus condition’ and ‘stimuli condition is reported here (Appendix H).

channels that were analysed. Outlier checking was conducted and data-points greater than three standard deviations above the mean were identified as outliers (Tabachnick & Fidell, 2013). To maintain the range and relative ordering of scores, outliers were replaced with a value .1 below this three standard deviation cutoff range (Osborne & Overbay, 2004; Tabachnick & Fidell) and less than 1% of the data was replaced. Greenhouse-Geisser corrections were made where appropriate and significance levels were maintained at alpha <.05. To control for multiple comparisons Sidak-corrected pairwise comparisons were used to test for significant differences between individual means, where necessary, and 95% confidence intervals [95% CI] are reported. To also control for multiple comparisions, effect sizes measured using partial eta squared (η_p^2) and Cohen's *d* (Cohen, 1988) were reported for results involving Group differences to provide a clinically relevant effect size. Bonferroni correction was applied to control for multiple comparisons for correlational anslyses. Data were analysed using the Statistical Package for the Social Sciences (SPSS; version 21). Obtained results involving electrode site are not reported unless involved in an interaction of theoretic significance with Group or Condition (see Appendix E for full ERP analyses summary; Appendix O).

8.4. Results

8.4.1. Salivary Progesterone

A univariate ANOVA demonstrated that women in the midluteal phase had significantly higher progesterone levels (*M*=195.04, *SD*=93.39, *Median*=177.50) than women in the early follicular phase (*M*=89.65, *SD*=91.92, *Median*=65.35), *F*(2,81)=20.70, *MSE*=6553.74, $p<.001$, $\eta_p^2=.359$, *d*=1.33 [*H*(1)=9.59, *p*=.002][6].

8.4.2. Clinical and Demographic Data

No significant differences were found between men, early follicular women, and midluteal women in age, depressed mood, anxiety, or stress (Table 1).

8.4.3. Picture Rating Task

As shown in Table 1, early follicular women rated the low-arousing pleasant images as significantly more pleasant than both midluteal women and men (*ps*<.001) and the high-arousing pleasant images as significantly more pleasant than midluteal women (*p*<.001). Both early follicular and midluteal women rated the low-arousing unpleasant (EF: *p*<.001; ML: *p*=.006) and high-arousing unpleasant (EF: *p*=.003; ML: *p*<.001) images as being significantly more unpleasant relative to men. Midluteal women rated the low-arousing pleasant images as significantly more arousing than did men (*p*=.002). Early follicular (*p*=.002) and midluteal (*p*<.001) women both rated the low-arousing unpleasant images as more arousing than men. No other significant differences in valence or arousal ratings for early follicular women, midluteal women, or men were found.

8.4.4. Electrophysiological Data

The grand mean average waveform at analysed sites for responses to each Condition, according to Group, is depicted in Figure 2.

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[6] Due to concerns of potential non-normality of salivary hormonal data, a non-parametric equivalent test (Kruskal-Wallis) was conducted to ensure any potential non-normality did not bias the results; these showed no contradictory results.

Table 1

Mean Scores for Age, Depressed Mood, Anxiety, Stress, and Valence and Arousal Ratings for Early Follicular Women, Midluteal Women, and Men

Variable	Early Follicular Women	Midluteal Women	Men	*F*	*p*	ηp^2
Age	23.54 (6.60)	23.45 (7.51)	24.41 (7.16)	.414	.66	.016
Depressed Mood	5.18 (8.71)	4.76 (6.44)	3.30 (3.45)	.616	.54	.015
Anxiety	3.64 (4.57)	4.62 (4.84)	2.85 (3.21)	1.198	.31	.029
Stress	8.11 (6.80)	8.14 (6.59)	6.04 (5.16)	1.023	.36	.025
Valence						
High PL/Low AR	8.04 (.72)	7.20 (.66)	7.21 (1.02)	9.93	<.001	.197
High PL/High AR	7.91 (1.10)	6.86 (.87)	7.46 (1.17)	7.15	.001	.150
High UNPL/Low AR	1.96 (.85)	2.11 (1.12)	2.91 (.80)	8.02	.001	.165
High UNPL/High AR	1.61 (1.05)	1.16 (.31)	2.33 (.80)	15.95	<.001	.282
Arousal						
High PL/Low AR	3.15 (.92)	3.89 (1.42)	2.59 (1.62)	6.49	.002	.183
High PL/High AR	6.94 (1.78)	6.18 (1.66)	6.94 (1.08)	2.25	.11	.053
High UNPL/Low AR	4.02 (1.01)	4.93 (2.08)	2.64 (.88)	17.70	<.001	.304
High UNPL/High AR	7.03 (1.95)	6.45 (3.19)	6.70 (1.90)	.410	.67	.010

Note. Standard Deviations in parentheses; PL = Pleasant, UNPL = Unpleasant; AR = Arousing.

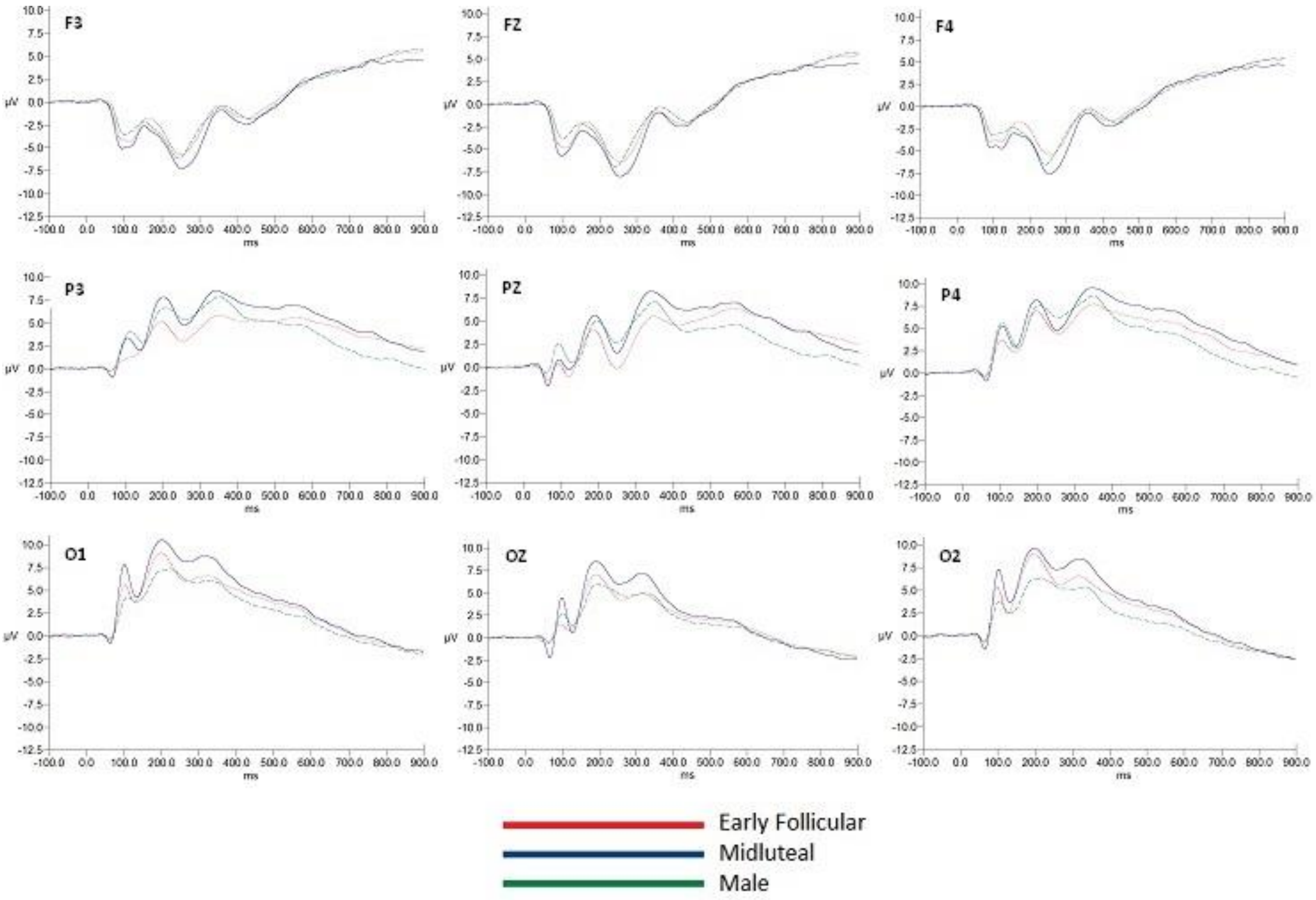

Figure 2. Grand mean average waveforms at analysed sites collapsed across valence and arousal for early follicular women, midluteal women, and men.

8.4.4.1. Early Processing: P1

The P1 peak amplitude data revealed a significant main effect of Group, *F*(2,81)=3.95, *MSE*=390.90, *p*=.02, η_p^2=.089. Sidak post-hoc tests showed that midluteal women (*M*=7.59, *SE*=.95, 95% CI [5.71, 9.48]) had significantly higher P1 amplitude than men (*M*=3.76, *SE*=.98, 95% CI [1.81, 5.72], *p*=.02) with a large effect size (*d*=.79). Midluteal women also had larger P1 amplitude than early follicular women (*M*=5.58, *SE*=.97, 95% CI [3.66, 7.50], *p*=.36, *d*=.4), who showed greater amplitude relative to men (*p*=.47, *d*=.36), but these differences did not reach significance. A main effect of Site was also found, *F*(1.75,141.61)=27.66, *MSE*=36.70, *p*<.001, η_p^2=.255. These effects were superseded by a significant Group × Site interaction, *F*(3.50, 81)=2.73, *MSE*=57.29, *p*=.04, η_p^2=.063 (see Figure. 3). Breakdown analysis by Group showed that midluteal women (*M*=9.06, *SE*=1.04, 95%CI [6.98, 11.13]) had higher P1 activity compared to men (*M*=4.23, *SE*=1.08, 95%CI [2.08, 6.48]) at O1 (*p*=.006, *d*=.90) site. Midluteal women (*M=7.92*, *SE*=.97, 95%CI [6.06, 9.85]) also showed greater P1 activity at O2 site relative to men (*M*=3.76, *SE*=1.00, 95%CI [1.78, 5.77], *p*=.01, *d*=.83). There were no other significant main effects or interactions for P1 amplitude.

8.4.4.2. Early Processing: N1

The N1 peak amplitude data revealed a significant main effect of Group, *F*(2,81)=4.17, *MSE*=113.90, *p*=.02, η_p^2=.093, and Site, *F*(1.6,136.92)=22.38, *MSE*=1.89, *p*<.001, η_p^2=.216). Sidak post-hoc tests for Group showed that midluteal women (*M*=-7.44, *SE*=.51, 95%CI[-6.42, -8.46]) had significantly higher N1 amplitude compared to men (*M*=-5.38, *SE*=.53, 95%CI[4.32, -6.43], *p*=.02) which reflected a moderate to large effect size (*d*=.74; Figure. 4). Midluteal women also had larger N1 amplitude than early follicular women (*M*=-6.90, *SE*=.52, 95%CI[-5.86, -7.93], *p*=.84, *d*=.16), who showed greater amplitude relative to men (*p*=.13, *d*=.58), but these differences did not reach significance. Follow-up tests for Site showed that N1 at FZ (*M*=-6.91, *SE*=.32, 95% CI [-6.27, -7.55]) was significantly higher than at both F3 (*M*=-6.43, *SE*=.29, 95% CI [-5.85, -7.01]) and F4 (*M*=-6.38, *SE*=.30, 95% CI [-5.78, -6.98]) (*ps*<.001). There were no other significant main effects or any significant interactions for N1 amplitude.

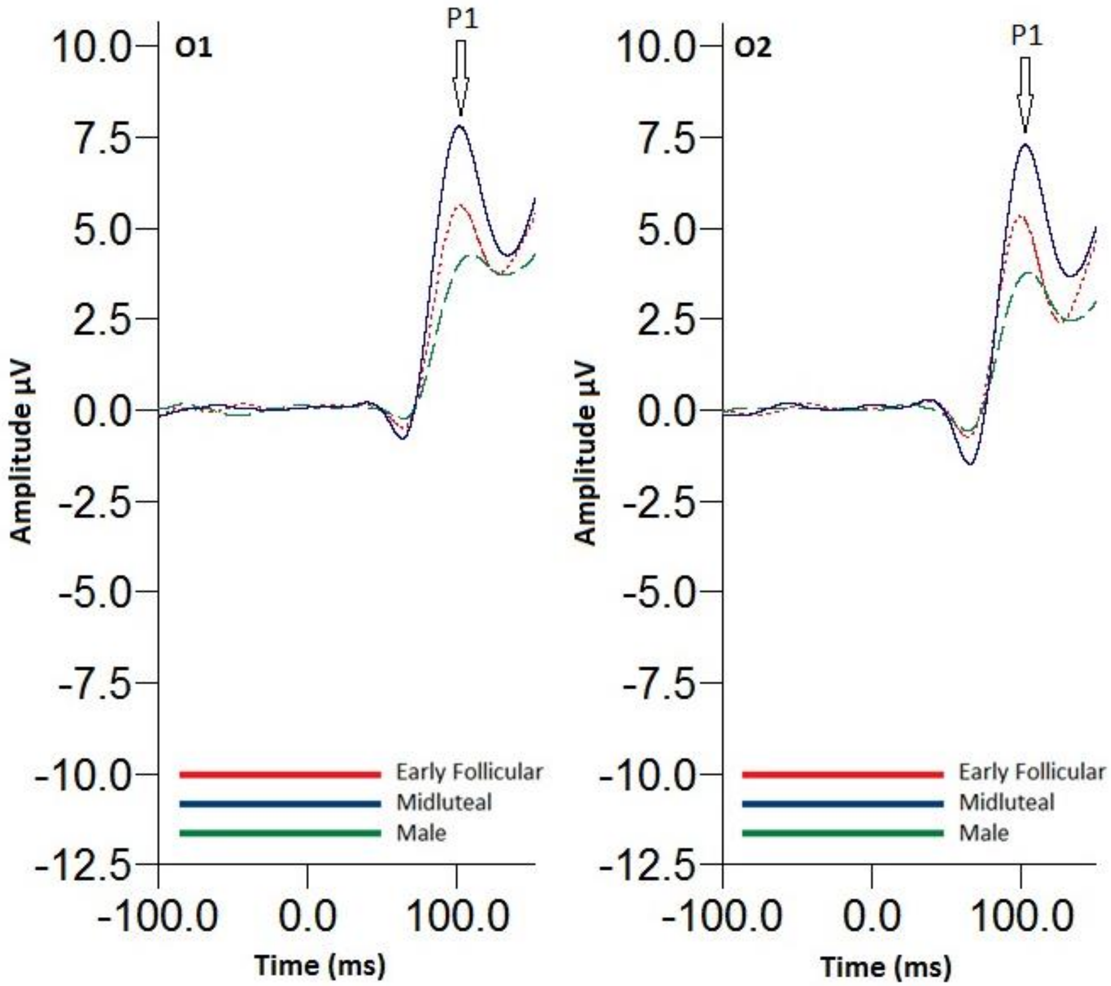

Figure 3. The Group × Site interaction for P1 amplitude at O1 and O2 site collapsed across valence and arousal.

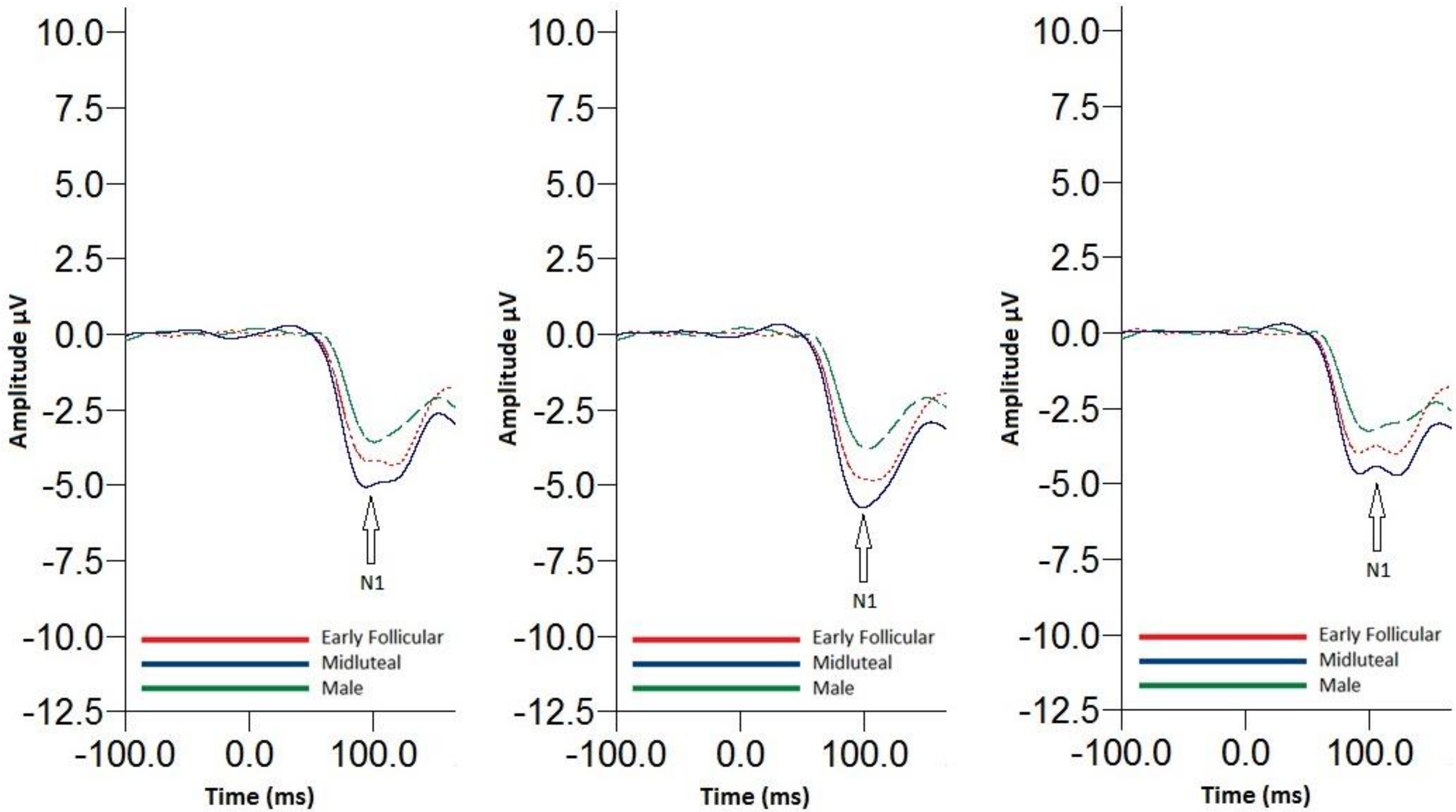

Figure 4. N1 amplitude collapsed across valence and arousal for early follicular women, midluteal women, and men at F3, FZ, and F4 sites.

8.4.4.3. Middle Processing: N2

The N2 peak amplitude data showed significant main effects of Condition, $F(3.27, 265.15)=19.13$, $MSE=22.13$, $p<.001$, $\eta_p^2=.191$, and Site, $F(1.63, 131.98)=34.87$, $MSE=3.48$, $p<.001$, $\eta_p^2=.301$. Sidak post-hocs for Condition showed that N2 amplitude to high-arousing unpleasant stimuli ($M=-6.97$, $SE=.59$, 95% CI[-5.79, -8.15]) was significantly lower than to low-arousing unpleasant ($M=-9.88$, $SE=.52$, 95% CI[-8.85, -10.91], $p=.001$) and high-arousing pleasant ($M=-8.75$, $SE=.49$, 95% CI[-7.78, -9.72], $p<.001$) stimuli. N2 amplitude to low-arousing unpleasant stimuli was shown to be significantly higher than low-arousing pleasant ($M=-7.94$, $SE=.48$, 95% CI[-6.98, -8.90], $p<.001$) and high-arousing pleasant ($p=.004$) stimuli. Sidak post-hocs for Site showed that N2 amplitude was significantly higher at FZ ($M=-9.15$, $SE=.49$, 95% CI[-8.18, -10.12]) compared to at F3 ($M=-8.24$, $SE=.45$, 95% CI[-7.34, -9.14]) or F4 ($M=-8.41$, $SE=.46$, 95% CI[-7.49, -9.32]) ($ps<.001$). There were no other significant main effects or interactions for N2 amplitude.

8.4.4.4. Late Processing: P3

The P3 peak amplitude data revealed significant main effects of Condition, $F(3.35,271.41)=106.94$, $MSE=18.48$, $p<.001$, $\eta_p^2=.569$, and Site, $F(1.97, 159.52)=22.82$, $MSE=14.79$, $p<.001$, $\eta_p^2=.220$. Sidak post-hoc tests for Condition demonstrated that P3 amplitude was significantly higher to high-arousing unpleasant ($M=12.75$, $SE=.64$, 95% CI[11.47, 14.03]) compared to low-arousing unpleasant ($M=8.13$, $SE=.50$, 95% CI[7.14, 9.12]), neutral ($M=7.33$, $SE=.51$, 95% CI[6.31, 8.35]), low-arousing pleasant ($M=6.13$, $SE=.51$, 95% CI[5.12, 7.15]), and high-arousing pleasant ($M=7.37$, $SE=.54$, 95% CI[6.30, 8.43]) stimuli (*ps*<.001). Low arousing unpleasant stimuli were shown to have higher P3 activity than low-arousing pleasant stimuli (*p*<.001). Neutral (*p*=.003) and high-arousing pleasant compared with low-arousing pleasant stimuli (*p*=.001) were also shown to elicit higher P3 amplitude. Sidak post-hoc tests for Site showed that P3 amplitude was significantly higher at P4 (*M*=9.30, *SE*=.53, 95% CI[8.25, 10.35]) compared to P3 (*M*=8.19, *SE*=.48, 95% CI[7.24, 9.13]) and PZ (*M*=7.54, *SE*=.55, 95% CI[6.44, 8.64]) sites (*ps*<.001). No other significant main effects or any other significant interactions were found for P3 amplitude.

8.4.4.5. Late Processing: LPP

The LPP mean amplitude data showed a significant main effect of Condition, $F(3.12, 252.42)=121.92$, $MSE=15.37$, $p<.001$, $\eta_p^2=.601$. Sidak post-hoc tests showed LPP amplitude to be significantly higher to high-arousing unpleasant (*M*=8.80, *SE*=.55, 95% CI[7.70, 9.90]) compared to low-arousing unpleasant (*M*=4.23, *SE*=.40, 95% CI[3.44, 5.02]), neutral (*M*=3.34, *SE*=.35, 95% CI[2.65, 4.04]), low-arousing pleasant (*M*=3.00, *SE*=.36, 95% CI[2.28, 3.72]), and high-arousing pleasant (*M*=3.45, *SE*=.35, 95% CI[2.75, 4.16]) stimuli (*ps*<.001). LPP amplitude was also shown to be significantly higher to low-arousing unpleasant stimuli compared to neutral (*p*=.02), high-arousing pleasant (*p*=.022), and low-arousing pleasant (*p*<.001) stimuli. No other significant main effects or interactions were found for LPP amplitude[7].

[7] To address findings of negativity bias in women in previous studies that did not control for menstrual phase, early follicular and midluteal women were collapsed together to allow cortical activity to be compared between men and all women in the study. Re-analysis of the data showed evidence of a negativity bias but only for the LPP component – we found that early follicular and midluteal women averaged together displayed significantly higher LPP amplitude to the highly arousing unpleasant stimuli compared to men (*p*=.03). No other significant main effects or interactions were found. We did not replicate the negativity bias in early negative components in women, but our study had an equal representation of midluteal

8.4.5. Relationship between between Progesterone or Anxiety (DASS) and ERP Components

To further examine the significant 'Group' effects specifically, planned correlations between progesterone and the relevant ERP components collapsed across their respective sites were performed using Pearson's product-moment coefficients (Pearson's *r*). As displayed in Appendix E, while no relationship was found between progesterone and P1 amplitude during the Low-Arousing Pleasant or Neutral conditions, significant correlations were found between progesterone and P1 during the High-Arousing Pleasant, and Low- and High-Unpleasant conditions. However, following Bonferroni correction only the correlation between progesterone and P1 during the High-Arousing Unpleasant condition remained significant, indicating that P1 amplitude in response to highly-arousing unpleasant stimuli increased as progesterone levels increased. Significant relationships were found between progesterone and N1 amplitude during all five conditions. However, once Bonferroni was applied only the correlations between progesterone and N1 during the Low- and High-Arousing Pleasant and Low-Arousing Unpleasant conditions were significant, indicating a relationship between increased progesterone levels and increased N1 amplitude during these conditions. In general, progesterone was significantly correlated with ERP amplitudes of the effects where we observed 'Group' differences. This is indicative of a direct role of progesterone in influencing the obtained 'Group' findings.

Pearson's product-moment coefficients were also calculated to examine the relationship between anxiety levels (as measured by the DASS) and the

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and early follicular women, and this may have differed from previous studies (we do not know the number of women in different menstrual phases in earlier studies, but there is more likelihood (2 out of 3) of testing women in the follicular phases than in the midluteal).

ERP components collapsed across their respective sites to examine individual differences. No significant or trend-level correlations between anxiety and any ERP component were revealed following Bonferroni correction for five comparisons (Appendix E).

8.5. Discussion

This study investigated the impact of menstrual phase (specifically the early follicular and midluteal phases) on the processing of visual emotional stimuli and examined the question of whether the midluteal phase is associated with a specific negativity bias to unpleasant stimuli or with more generalised enhancement of early visual processing. Findings revealed midluteal women had significantly increased early ERP amplitudes (P1, N1) compared to men, and had larger P1 and N1 amplitudes than early follicular women. Notably, this effect was observed across unpleasant, pleasant, and neutral stimuli, which does not support a negativity bias. Rather, it suggests that there is generally-enhanced early visual processing in midluteal women rather than a specific emotion-processing bias. The impact of menstrual phase and sex were only observed in early automatic ERP processes, as later conscious ERP processes (P3, LPP) only showed condition effects, reflecting greater processing of highly-arousing unpleasant stimuli compared to the other stimulus conditions. This study presents novel ERP evidence for a modulation of early visual processing by menstrual phase, with women in the midluteal phase demonstrating greater early automatic visual processing of emotional stimuli.

8.5.1. Early Preconscious Emotion Processing

The present study revealed greater early cortical processing of visual emotional stimuli in women in the midluteal phase compared to men, as midluteal women had significantly greater P1 amplitudes to stimuli (regardless of valence and arousal) relative to men over occipital regions. Given that P1 activation at occipital sites reflects the earliest stage of automatic visual attention (Avitabile et al., 2007; Hillyard & Anllo-Vento, 1998; Luck et al., 2000), our finding of increased P1 amplitude suggests that midluteal women display greater early automatic visual processing of visual emotional stimuli relative to early follicular women and particularly to men. This interpretation is consistent with previous visual research which has demonstrated that high progesterone levels (as observed in midluteal women) are related to increased capacity for sustained visual attention (Solis-Ortiz & Corsi-Cabrera, 2008), greater visual perception ability (Wijayanto et al., 2009), and enhanced visual memory (Phillips & Sherwin, 1992). Our findings further confirm more recent research which showed midluteal women, compared to follicular women and men, to have greater emotional memory, and enhanced imagery reactivity, strength and vividness, with these effects predicted by progesterone level (Wassell et al., 2015a, 2015b).

Neuroimaging research has demonstrated a link between visual processing regions (such as the occipital cortex) and the amygdala, with amygdala reafferents thought to be involved in the early processing of stimuli in the visual cortex (de Kloet et al., 2005). Accumulating neuroimaging evidence reveals that the amygdala is predominantly activated when processing visual stimuli (relative to other sensory stimuli; Boubela et al., 2015; Phan et al., 2002), salient stimuli (Davis & Whalen, 2001; Edminston et al., 2013; Liberzon et al., 2003), as well as emotional stimuli (Costafreda et al., 2008; Stevens & Hamann, 2012). Research also reveals amygdala activation to neutral stimuli if it is salient and important to a task (Cooney et al., 2006; Davis & Whalen, 2001; Fusar-Poli et al., 2009; Schwartz et al., 2003). This can be interpreted to reflect the central influence of amygdala inputs in the modulation of early visual processing of visual stimuli.

More recently, Rotshtein et al. (2010) examined ERPs to facial expressions in patients with amygdala damage and healthy controls, and demonstrated reduced P1 amplitude at occipital sites in those with amygdala damage, and concluded that the amygdala has a substantial impact on early automatic visual processing as reflected in the occipital P1. Therefore, convergent evidence suggests that P1 may reflect visual occipital activation which is influenced by amygdala activity to salient stimuli, and our finding of increased occipital P1 amplitude in midluteal women is thus consistent with evidence of increased amygdala activation in midluteal women (Andreano & Cahill, 2010; Bayer et al., 2014; Gingnell et al., 2012) and of increased visual processing and imagery (Wassell et al., 2015a, 2015b).

The N1 component reflects early automatic attention allocation and is maximal at frontal sites reflecting frontal cortical activity (Dong et al., 2011; Hajcak et al., 2010), while the mid-latency frontal N2 ERP component has been associated with selective attention and conscious discrimination of visual stimuli (e.g., Patel & Azzam, 2005). In the current study, midluteal women exhibited higher N1 amplitude relative to men, which is in accordance with previous evidence of increased N1 and N2 in women (e.g., Gardener et al., 2013; Li et al., 2008; Lithari et al. 2010), and greater N2 amplitude to unpleasant stimuli in midluteal women compared with mid- to late- follicular women (Wu et al., 2014). Notably, these previous studies revealed this effect specifically for unpleasant emotional stimuli reflecting a female negativity bias, whereas we found increased early ERP amplitudes across all valence and arousal conditions including to neutral stimuli.

When considering the lack of evidence for the motivational model or a female negativity bias, an alternative explanation may be that women, particularly midluteal women, display a reduced positivity bias. A positivity bias has been found in a sample of men and refers to pleasant stimuli eliciting comparable or even more pronounced responses compared with unpleasant stimuli (e.g., Brown et al., 2012) or neutral stimuli (Pool et al., 2016). Hence, midluteal women may have a lowered attentional bias for both pleasant and unpleasant stimuli in both early and late processing.

Further, of key importance is that previous studies revealing a negativity bias (or reduced positivity bias) in women typically did not control for menstrual phase. Our finding of increased visual processing of all stimuli in midluteal women is consistent with a recent ERP study examining menstrual phase, which revealed increased LPP amplitudes to all emotional and neutral stimuli in the mid-late luteal phase (Zhang et al., 2013). It is possible that failure to control for menstrual phase reduces the influence of progesterone, which is strongly associated with generally enhanced visual processing (Avitabile et al., 2007). Mixing women in both follicular phases, which are associated with low progesterone, with women in midluteal phases associated with high progesterone, reduces the impact of progesterone and thus may increase the likelihood of finding a negativity bias in women. Our interpretation of enhanced visual processing in midluteal women is supported by the correlational data which showed a relationship between increased progesterone levels, as observed during the midluteal phase, and increased P1 and N1 amplitudes.

Methodological differences may have also influenced the divergent findings, as previous studies have used emotion regulation tasks or attention tasks embedded in their design (Gardener et al., 2013, Wu et al., 2014) or have used different types of emotional stimuli (Li et al., 2008). Our experimental task was very similar to Lithari et al. (2010), however we did not replicate their findings of a negativity bias in N1 or N2. This may be due to the inclusion of a neutral condition in the current study or to our analysis of negative ERP components at frontal sites in comparison to Lithari et al. who measured N1 and N2 predominantly at parietal sites.

8.5.2. Late Conscious Emotional Processing

A Condition main effect was found in P3 and LPP amplitudes, revealing increased amplitudes to high-arousing unpleasant stimuli compared to all other stimulus conditions. This finding is suggestive of a negativity bias (across all groups) to arousing unpleasant stimuli, given that these later ERP components reflect conscious processing resources being directed to a stimulus (Feng et al., 2012a; Olofsson et al., 2008). The current finding of greater later conscious processing to highly-arousing unpleasant stimuli replicates several previous ERP studies (e.g., Li et al., 2008). We found no sex or menstrual phase effects during late conscious emotional processing, which is in contrast to previous research which has shown increased late LPP amplitudes to emotional stimuli associated with menstrual phase (e.g., Zhang et al., 2013). This discrepancy potentially arises from methodological differences between studies as previously discussed. Notably, in contrast to the current study, the previous ERP menstrual phase studies reporting increased N2 (Wu et al., 2014) or LPP (Zhang et al., 2013) amplitudes included a late follicular group, which is characterised by particularly high estradiol levels. Therefore, divergent findings may be related to the different menstrual phases assessed across studies and the inclusion of a high estradiol group. We cannot examine this issue given the artefactual estradiol data in the current study. To clarify this further, future research needs to examine ERP responses to emotional stimuli across all three menstrual phases in women compared to men.

8.5.3. Limitations and Future Research

Whilst this study addresses an important gap in the literature and finds novel ERP evidence of enhanced automatic visual processing associated with the midluteal menstrual phase, there are several limitations to this study. Firstly, in an attempt to replicate and extend recent ERP sex difference studies, we employed a passive viewing task to avoid any potential confounds of emotion and superimposed cognitive processing. However, since some of our divergent findings may relate to this methodological difference, future research should examine the impact of menstrual phase using an active task that includes a behavioural index of visual processing to aid interpretation of ERP data. Secondly, we employed a between-group design and collected a cross-sectional sample of participants due to restrictions on recruiting a longitudinal sample. This may have led to an underestimation of differences between menstrual phases due to inter-individual variability between groups. Similarly, while we did not observe mood differences between the groups, the impact of menstrual phase and of progesterone may vary between individuals. An optimal design for this study is a within-group design, where women are tested across their different menstrual phases to control for individual differences. Further, this study only examined the early follicular and midluteal phase and future research would benefit from including a late follicular phase in order to examine the impact of high estradiol separately from that of high levels of progesterone. Unfortunately, the estradiol data in this study could not be analysed due to artefact; while standardised storage and assay protocols were followed, data collection occurred over a 12-month period, which may have led to a deterioration in saliva samples that impacted on estradiol values. Future research should attempt to collect blood samples for more reliable estimates of estradiol. Future research needs to adopt standardised emotion processing paradigms and examine the impact of estradiol and progesterone on ERPs, specifically.

8.5.4. Conclusion

These limitations notwithstanding, the current study revealed novel evidence that early automatic visual processing is impacted by menstrual phase. Specifically, women in the midluteal phase displayed greater P1 amplitudes over occipital regions and greater N1 amplitude over frontal regions in response to visual stimuli than men. Notably, these effects were observed to unpleasant, pleasant, and neutral stimuli, indicating general enhancement of early visual processing associated with the midluteal phase rather than a specific negativity bias. Furthermore, the observed effect of menstrual phase was restricted to early automatic cortical processing, and was not evident in later cognitive processing. Rather than a negativity bias or greater reactivity to emotional stimuli, these results are in line with the potential mechanism of a generalised increase in reactivity to all visual stimuli involved in the heightened female risk for anxiety, but this study reveals that it is also essential to consider menstrual phase effects. These findings thus highlight the importance of considering the impact of menstrual phase on visual processing and of examining early automatic and later conscious processing of visual emotional stimuli.

8.6. Acknowledgements

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8.7. Implications for the Program of Research

To investigate whether menstrual phase is associated with the negativity bias or motivational model, Study 2 compared the cortical processing of visual emotional stimuli of early follicular women, midluteal women, and men using high temporal resolution ERP methodology. The findings revealed novel evidence of a significant effect of menstrual phase in early visual processing as midluteal women were shown to have generally enhanced early automatic visual reactivity compared with early follicular women and men. Participants thus did not show differentiation in emotion processing and no definitive evidence for the negativity bias or motivational model was established in Study 2.

Heightened early emotional reactivity is theorised to result in impaired emotion regulation capacity (Sheppes & Gross, 2011). Excessive early emotional reactivity and difficulty regulating negative emotional states have been implicated in anxiety and depressive disorders for which women display vulnerability relative to men (e.g., Cisler & Koster, 2010; Etkin, 2009; Farb et al., 2012; Kessler et al., 2005; McLean et al., 2011; Price & Drevets, 2012; Waugh et al., 2012). Only a small number of studies investigating sex differences in emotion regulation have been conducted, and the majority have used low-temporal resolution neuroimaging technologies and have not controlled for menstrual phase. The finding from Study 2 suggests that women in the midluteal phase have a generalised greater visual reactivity, which may impact on later emotion regulation processes. Such a finding highlights the need for further research to explore whether menstrual phase impacts emotion processing and regulation processes.

Previous ERP research has been conducted to examine the impact of menstrual phase on emotion processing (e.g., Wu et al., 2014; Zhang et al., 2013, 2015). Similarly, ERP research has examined sex differences in emotion regulation (e.g., Gardener et al., 2013). However, to our knowledge no previous ERP emotion regulation studies have investigated sex differences and the impact of menstrual phase on emotion regulation processing. Accordingly, Study 3 was designed to address this void in the literature. The aim of Study 3 was thus to examine the impact of menstrual phase on emotional reactivity and emotion regulation. To this end, we utilised an emotion regulation task and high temporal resolution ERPs to investigate the effect of menstrual phase on the cortical processing of early preconscious emotional reactivity, early conscious attention allocation, and later conscious emotion regulation (reappraisal and suppression) in early follicular women, midluteal women, and men.

CHAPTER 9: THE IMPACT OF SEX AND MENSTRUAL PHASE ON EMOTION REGULATION

Females in the Midluteal Phase of the Menstrual Cycle Have Difficulty Suppressing the Processing of Negative Emotional Stimuli: An Event-related Potential Study

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9.1. Abstract

Emotion regulation deficits have been implicated in anxiety disorders and these internalising disorders are more prevalent in women than men. Few electrophysiological studies have investigated sex differences in emotional reactivity and emotion regulation controlling for menstrual phase. Event-related potentials were recorded from 28 early follicular women, 29 midluteal women, and 27 men, who completed an emotion regulation task. A novel finding of increased N2 amplitude during suppression was found for midluteal women compared with men and early follicular women. These findings suggest midluteal women are significantly less able to suppress cortical processing of negative stimuli compared to men. This was confirmed by behavioural ratings data which revealed that while both early follicular and midluteal women reported more distress than men, midluteal women also reported greater effort when suppressing their responses. P1 and N1 components were increased in midluteal women compared to men regardless of instructional set, reflecting greater early attentional processing. No sex or menstrual phase differences were apparent in P3 or LPP. This study underscores the importance of considering menstrual phase when examining sex differences in the cortical processing of emotion regulation and demonstrates that midluteal women have deficits in down-regulating their behavioural and cortical responses.

9.2. Introduction

Anxiety disorders occur at approximately twice the rate in women compared to men (Australian Bureau of Statistics, 2007, 2015; Kessler et al., 1994; Kessler et al., 2005; McLean et al., 2011), but the mechanisms underlying the higher female prevalence rates for these internalising disorders is unclear. Proposed mechanisms that underlie anxiety disorders include emotional reactivity and deficits in the regulation of negative emotional states (e.g., Cisler & Koster, 2010; Etkin, 2009; Farb et al., 2012; Price & Drevets, 2012; Waugh et al., 2012). Emotion regulation processing involves both early emotional reactivity and later emotion regulation components (Gross et al., 2011). Early emotional reactivity refers to the preconscious processing and automatic allocation of attention to emotionally salient stimuli (Lithari et al., 2010). Early emotional reactivity precedes and influences later emotion regulation, which involves the conscious regulation of one's experience of emotionally pertinent stimuli (Gross et al.). Emotional responses to emotion-inducing stimuli may be increased, decreased, or maintained following the use of emotion regulation strategies (Gross, 2007; Gross et al.).

In line with the Process Model of Emotion Regulation (PMER; Gross & Thompson, 2007), two primary emotion regulation strategies used by individuals with anxiety for decreasing emotional responses are reappraisal and suppression. Reappraisal is an early antecedent-focussed strategy, involving cognitive modification of emotional responses by consciously altering the meaning of an emotion inducing stimulus to decrease its emotional influence (Goldin et al., 2008). Suppression is a later, response-focused strategy, which involves behavioural strategies for the reduction of emotionally expressive behaviour by concealing and avoiding emotions as they arise (Gross & John, 2003; Hajcak & Nieuwenhuis, 2006). The emotion literature demonstrates that suppression is typically a less adaptive strategy than reappraisal, as it can lead to a paradoxical increase in negative affect and physiological arousal compared to reappraisal which generally leads to decreased psychological distress and physiological arousal (Hofmann et al., 2012).

Functional magnetic resonance imaging (fMRI) methodology has been employed to map the neural networks of reappraisal and suppression by measuring cortical and subcortical activation during emotion regulation tasks. Goldin et al. (2008) compared the neural effects of reappraisal and suppression to unpleasant films using fMRI and found that the reappraisal instruction elicited early prefrontal cortical activation, decreased amygdala and insular activity, and decreased negative emotion experience, whereas suppression elicited late prefrontal cortex activity and increased amygdala and insular response (Goldin et al., 2008).

While these findings are in line with the predictions of the PMER, the Goldin et al. (2008) study is limited by the failure to control for sex differences. McRae et al. (2008) assessed neural activity during a reappraisal task and showed men to have reduced amygdala activity during emotion regulation compared to women, suggesting a greater capacity to regulate unpleasant emotional responses relative to women. Coupled with decreased amygdala activity, men also showed less activation of prefrontal regulatory networks involved in emotion regulation than women, which McRae et al. interpreted as reflecting more efficient emotion regulation processing in men as compared with women. In contrast, a second fMRI study examining reappraisal to unpleasant stimuli by Domes et al. (2010) found that men had greater prefrontal region activation than women, with no sex differences in amygdala activation. Inconsistencies in neuroimaging findings may be related to the poor temporal resolution of fMRI, which limits the delineation of precise temporal processes associated with early emotional reactivity and later emotion regulation.

The high temporal resolution of event-related potentials (ERPs) compared to neuroimaging techniques allows the delineation of sex differences in early emotional reactivity (P1 and N1 ERP components), early conscious attention (N2 ERP component), and late emotion regulation (P3 and late positive potential (LPP) ERP components) during reappraisal and suppression instructions. The P1 component is a positive wave form occurring approximately 100ms post-stimulus onset which indexes early preconscious visual processing (Hillyard & Anllo-Vento, 1998; Luck et al., 2000; Lusk et al., 2015). N1 and N2 are negative wave forms occurring approximately 100ms and 200ms post-stimulus onset which index early preconscious and early conscious attention allocation respectively (Dong et al., 2011; Schupp et al., 2006). P3 is a positive wave form that appears approximately 300ms post-stimulus which is thought to index conscious allocation of cognitive resources to emotionally salient stimuli (Moser et al., 2009; Olofsson et al., 2008). The LPP is a positive wave form occurring approximately 600ms post-stimulus onset which is considered a robust electrophysiological marker of later, conscious, response-related emotion regulation (Hajcak et al., 2010).

Despite growing evidence regarding the relevance of sex hormones for emotional processing (Toffoletto et al., 2014), previous sex differences and emotion regulation studies have typically failed to control for the influence of menstrual phase. Only a small number of recent ERP studies have investigated the impact of menstrual phase and these studies have reported conflicting results. Investigating the processing of neutral and moderately and highly unpleasant visual stimuli across mid-late luteal and mid-late follicular menstrual phases, Wu et al. (2014) found N2 amplitude to be greater to both moderately and highly unpleasant stimuli compared with neutral stimuli during the mid-late luteal phase, with no difference demonstrated during the mid-late follicular phase. This finding supports the negativity bias in women, and indicates that the processing bias is markedly stronger in midluteal women, which echoes recent neuroimaging findings (e.g., Andreano & Cahill, 2010). Examining how the early follicular, late follicular, and luteal menstrual cycle phases influence the evaluation of emotion, Zhang et al. (2015) showed luteal phase modulation of the LPP. In contrast to Wu et al. (2014), assessing ERPs to positive, negative, and neutral facial expressions during the early follicular, late follicular, and mid-late luteal menstrual phases, Zhang et al. (2013) demonstrated increased LPP amplitudes to *all* facial expressions during the mid-late luteal phase compared to the early follicular and late follicular phases. A recent study by Lusk et al. (2015) similarly found that midluteal women displayed increased automatic visual processing to emotional and neutral stimuli, and suggested that this greater early visual processing may have implications for later emotion regulation. Given the limbic system has been shown to be modulated by menstrual phase (Andreano & Cahill, 2010), there is a need for further research to explore whether menstrual phase impacts emotion regulation processing.

Few ERP studies have extended existing sex differences and emotion literature to investigate sex differences in emotion regulation. N1 and N2 amplitudes have been found to be significantly greater in women compared to men (Lithari et al., 2010) irrespective of emotion regulation instruction (Gardener et al., 2013). Similarly, while Li et al. (2008) revealed greater N2 and P3 amplitude in both men and women to highly unpleasant relative to neutral stimuli, moderately unpleasant stimuli were shown to produce increased N2 and P3 amplitudes in women but not men. P3 activation has been shown to reflect modulation of emotional responses before later emotion regulation processes (Moser et al., 2009; Olofsson et al., 2008). Modified by emotional instruction, LPP amplitude has been shown to be lower when one's emotional response is decreased and higher when emotional reactivity is increased (Hajcak & Nieuwenhuis, 2006; Moser et al.). In response to an 'increase' emotion instruction, women display greater LPP activation than men, but sex differences to a 'decrease' emotion instruction were not observed (Gardener et al.). Collectively, these ERP findings demonstrate increased early emotional reactivity and greater engagement of emotion regulation processes in women compared to men. To the best of our knowledge, no ERP emotion regulation studies have previously investigated sex differences and the impact of menstrual phase on emotion regulation processing.

The aim of the current study was to investigate the effect of menstrual phase on cortical processing during emotion regulation (reappraisal and suppression). We used high temporal resolution ERPs to investigate sex differences in the cortical processing of emotion regulation, controlling for menstrual phase. Specifically, we employed an emotion regulation task adapted from the methodologies of Goldin et al. (2008) and Moser et al. (2010) to compare conscious emotion regulation processing in men, women in their early follicular menstrual phase (characterised by low levels of estradiol and progesterone), and women in their midluteal menstrual phase (characterised by high levels of estradiol and progesterone). We anticipated that women in the midluteal phase would display greater emotional reactivity, as reflected by increased P1 and N1 amplitude to unpleasant stimuli, than men and women in the early follicular phase. We further expected this heightened reactivity to impact later emotion regulation processing. Specifically, we predicted that midluteal women would demonstrate greater difficulty down-regulating responses to unpleasant stimuli following emotion regulation instructions (reappraisal, and particularly suppression), as reflected by greater emotional distress and effort ratings and smaller reductions in P3 and LPP amplitudes, compared to men and early follicular women.

9.3. Method

9.3.1. Participants

Eighty four healthy, right handed, non-smoking Caucasian adults were recruited from first-year psychology undergraduates. Participants were 28 women in the early follicular phase of their menstrual cycle (day 2-6; *M*=3.54, *SD*=1.66; low estradiol/low progesterone; age range 18-44 years; *M*=23.54, *SD* =6.60), 29 women in the midluteal menstrual cycle phase (day 18-24; *M*=20.90, *SD*=1.86; high estradiol/high progesterone; age range 18-40 years; *M*=23.45, *SD* =7.51), and 27 men (age range 18-40 years; *M*=24.41, *SD* =7.16). Three women currently prescribed a combination contraceptive pill and tested on day 4 of their sugar pill while menstruating were included in the early follicular sample. Analyses of all data sets were conducted with and without the three women on contraceptives. Removal of these participants did not affect the findings and therefore the full early follicular sample (including those on the contraceptive pill) is reported (see Appendix L). To ensure accuracy of menstrual phase allocation, women contacted the investigator on day one of their menses and were tested in the early follicular phase when menstruating or were scheduled for testing during the midluteal phase, calculated from their first day of menstruation. Women were deemed ineligible for this study if they were pregnant or possibly pregnant, had been pregnant or given birth during the previous 12 months, reported a typical monthly menstrual cycle below 27 days or above 29 days, had currently or previously experienced abnormal or irregular menstrual cycles, menopause, or reported any type of abnormal hormonal condition. No women were excluded due to progesterone levels being inconsistent with expected menstrual phase levels or due to anovulatory cycles. Participants who reported medication use, substance abuse or dependence, a history of neurological disorders, brain injury or loss of consciousness greater than five minutes, mood disturbance, or anxiety in response to the visual stimuli in the experimental task were excluded from this study. It should be noted that the same participants were recruited for Lusk et al. (2015) and the current study, however, different experimental tasks (passive viewing versus emotion regulation) containing different stimuli, and completed in counter-balanced order were used. Participants gave written informed consent and this study had ethical approval from the Tasmanian Social Sciences Human Research Ethics Committee.

9.3.2. Stimuli and Materials

9.3.2.1. Depression, Anxiety, Stress Scale

Prior to testing participants completed the 42-item self-report Depression, Anxiety, Stress Scale (DASS; Lovibond & Lovibond, 1995) to provide an estimate of participant's level of depressed, anxious, and stressed mood on the day of testing. Each item is measured on a four-point Likert scale (0 = *did not apply to me at all*, 3 = *applied to me very much, or most of the time*). Participants' DASS responding and the scale scoring were completed according to the standardised instructions and used to provide an estimate of participants' mood state. The DASS is a highly reliable measure of depression (α = .95), anxiety (α = .90), and stress (α = .93) (Lovibond & Lovibond).

9.3.2.2. Emotion Regulation Scale

Participants completed the Emotion Regulation Scale (ERS; Gross and John, 2003) prior to experimental task completion to assess trait emotion regulation style. The ERS is a ten-item self-report measure of trait emotion regulation which assesses the extent of reappraisal and suppression emotion regulation strategies typically used. The ERS is composed of a reappraisal subscale (6-items) and a suppression subscale (4-items). Each item is measured on a seven-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*). The mean of ERS scores for each subscale was calculated to provide an estimate of the extent to which participants engaged in each emotion regulation strategy. Test-retest reliability for both scales is .69 (Gross & John, 2003), and Chronbach's alphas are α = .81 and α = .75 for the reappraisal and suppression subscale respectively (Amstadter & Vemon, 2008).

9.3.2.3. Emotion Regulation Task

A computer-based emotion regulation picture-viewing task adapted from Moser et al. (2010) and Goldin et al. (2008) was used. The task comprised two different blocks of emotion regulation instructions (Reappraisal and Maintain *or* Suppression and Maintain) and each block presented the same 60 highly arousing unpleasant International Affective Picture System (IAPS) (Lang et al., 2008) images[8] in randomised order which was counterbalanced according to Latin Square procedures. IAPS normative data guided image selection; similar to Moser et al. (2010; mean valence: 2.55; mean arousal: 6.48), the mean valence and arousal ratings were 2.81 and 6.04 respectively. The experimental images included scenes involving animal and human mutilation, injury, assaults, and death. Neutral stimuli were not presented, as it is not possible to regulate an emotional response to neutral a stimulus (Moser et al., 2010).

Each block contained 30 maintain and 30 regulation (Reappraisal *or* Suppression) trials. Consistent with the procedures of Goldin et al. (2008) and Moser et al. (2010), we included a maintain condition in each task instruction block as this was argued to minimise confounding of emotion regulation strategies which might conceal differences between regulation and the passive viewing (maintain) conditions (Moser et al.). 'Reappraisal' and 'Suppression' instructions were adapted from those used by Goldin et al. (2008), while the Maintain instruction was that used by Moser et al.. The Reappraisal prompt

[8] IAPS images used in this experiment - Animal Threat: 1033, 1050, 1120, 1202, 1205, 1300, 1301, 1303, 1304, 1310, 1321, 1525, 1820, 1931, 1932; Animal Mutilation: 6415, 9140, 9145, 9150, 9171, 9180, 9181, 9182, 9183, 9185, 9186, 9560, 9561, 9570, 9571; Human Threat: 3500, 3530, 6021, 6212, 6213, 6220, 6260, 6312, 6350, 6520, 6550, 6821, 6825, 6830, 9452; Human Mutilation: 3000, 3001, 3010, 3015, 3051, 3064, 3069, 3195, 3213, 3215, 3261, 3280, 9042, 9420, 9433.

was “think objectively” and participants were instructed to “think objectively to decrease any emotional response you might have to the image by viewing the image with a detached third person perspective, thinking of the image content as being not personally relevant, or thinking of the image content as being fake”. The Reappraisal instruction aimed to alter the antecedent interpretation of the stimuli to decrease participant’s emotional response. The Suppression prompt was “keep face still” and participants were instructed to “keep your face still but do not change the way you are feeling inside. Continue to experience your emotions as you normally would. But please keep your face still so that someone watching you could not tell how you are feeling inside”. The Suppression instruction aimed to reduce the emotional reaction to the stimuli experienced by the participants. The Maintain instruction prompt was “watch” and participants were instructed to “watch the image normally as you would if you were watching TV on your couch at home. Do not change the way you would normally respond to the image, and experience your emotions normally”. The instruction prompts also acted as a fixation point in the centre of the screen to orient the participant’s attention and instruct them in how to respond to the next upcoming image. Reappraise and Suppression instructions were presented in separate blocks to avoid any contamination of emotion regulation strategies within each block (e.g., switching from reappraisal to suppression on successive trials; Goldin et al., 2008; Monsell, 2003; Moser et al.). The instruction was presented for 3000ms, stimuli were then immediately presented for 5000ms, and an inter-stimulus interval of 3000ms then followed (see Figure 1).

9.3.2.4. Post-task Manipulation Check

Following the experimental task, a questionnaire was used to obtain qualitative responses from participants as a task manipulation check to assess capacity to follow emotion regulation instructions. Participants reported the strategies they had used when following each task instruction (Reappraisal, Suppression, or Maintain). Perceived emotional distress experienced while following each instruction type was rated on a seven-point Likert scale (1 = *very weak*, 7 = *very strong*). Perceived degree of effort required to regulate one's emotional reaction for each instruction strategy was also assessed on a seven-point Likert scale (1 = *very little*, 7 = *very much*).

9.3.3. Salivary Estradiol and Progesterone

Salivary measures of baseline estradiol and progesterone were taken to enable confirmation of menstrual cycle states in women (Gandara et al., 2007). Participants refrained from consuming food, caffeine, and nicotine for three hours prior to the study, and avoided alcohol or excessive exercise for 24 hours prior to the study in order to control for potential confounds on hormonal or ERP responses (e.g., Brot et al., 1995; Fabiani et al., 2000; Polich, 2007). Saliva samples were self-collected from participants in tubes using the standard passive drool method (Shirtcliff et al., 2001), immediately frozen, and stored at -20^{o}C until assay. On analysis day, specimens were thawed and centrifuged at 1500×*g* for 15 minutes at room temperature. Estradiol and progesterone concentrations were determined by enzyme immunoassay with commercially available kits (Q-111 HS Salivary 17-ß Estradiol EIA and Q-112 Salivary Progesterone EIA kits; rabbit anti-estradiol/progesterone antibodies; Salimetrics, State College, Pennsylvania, USA) in the Pathology Laboratory in the Division of Pharmacy at the University of Tasmania (UTAS), Australia. Estradiol data were not analysed since extremely low values in all participants suggested artefactual data.

9.3.4. Procedure

Participants attended the Cognitive Neuroscience Laboratory at UTAS for one two-hour testing session. Participants completed the ERS (Gross and John, 2003) and DASS (Lovibond & Lovibond, 1995) and saliva samples were collected. Participants were prepared for EEG recording as described below and were then seated 0.5 meters from a 17-inch computer screen in a sound-attenuated room. Participants were instructed to maintain eye contact with the computer screen and to limit eye and body movements throughout the emotion regulation task.

Similar to Moser et al. (2010), prior to the experimental task presentation, participants completed two 15-trial training blocks to familiarise them to the task and ensure that they understood and could adhere to the Reappraisal, Suppression, and Maintain instructions. During the first training block, participants were required to verbally report the strategies they were using to appraise the stimuli in accordance with the instructional prompts. This training block provided the investigator with the opportunity to mould the strategies used by the participants and establish whether they understood the task. During the second training block, participants were required to silently produce the appropriate strategies that they would use to appraise the stimuli in line with the instructional prompts as they would do during the experimental task. Participants viewed the stimuli presented on the screen, in line with each instruction, and were told that they would be asked questions regarding the stimuli (i.e., perceived valence/arousal) after the emotion regulation task to ensure that they attended to the stimuli. As an additional instruction manipulation check, the investigators reviewed the participants' responses on the post-task questionnaire to determine whether or not participants understood the instructions and reported using strategies typical of previous research findings (e.g., Ochsner & Gross, 2005) before their data were included in analysis. Following the task, each stimulus was then independently rated for level of valence and arousal by participants on a 9-point Likert scale adapted from the IAPS normative data rating scale (Self-Assessment Manikin; Bradley & Lang, 1994): Valence (1 = *highly unpleasant*, 5 = *neutral,* 9 = *highly pleasant*); Arousal (1 = *not at all exciting/arousing*, 5 = *moderately arousing*, 9 = *highly exciting/arousing*).

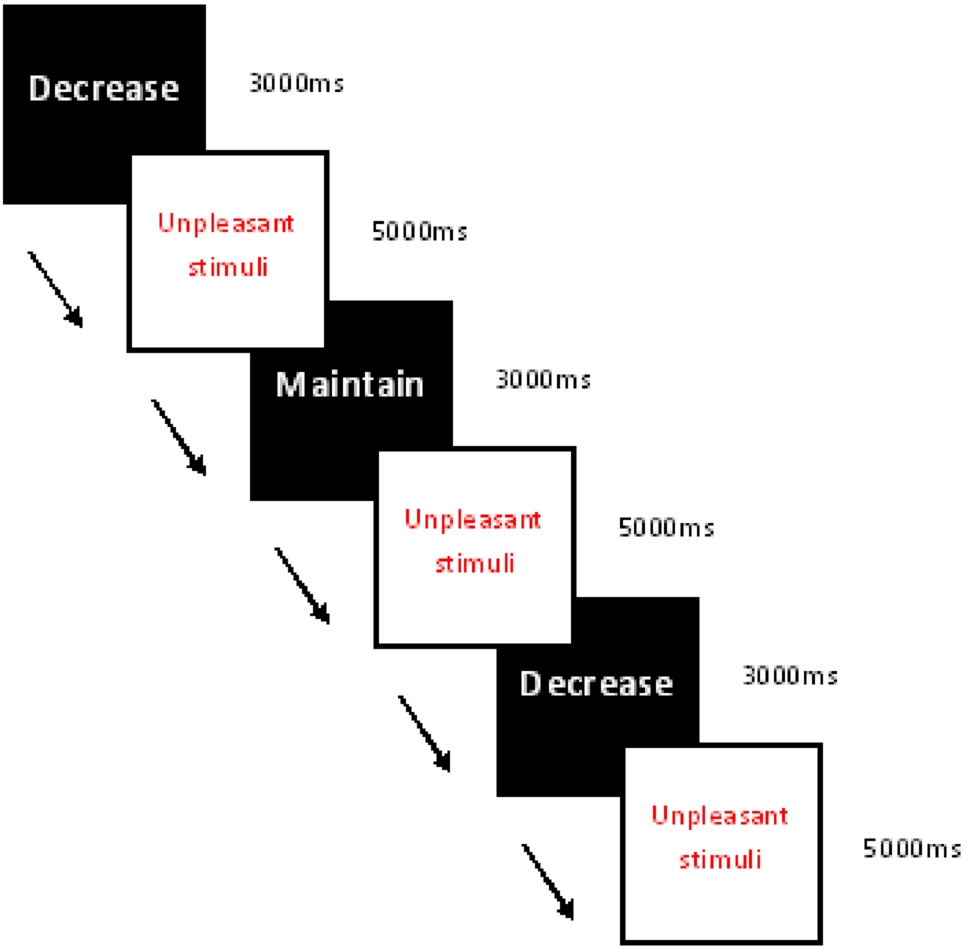

Figure 1. Flowchart of the emotion regulation task stimulus presentation.

9.3.5. Electrophysiological Apparatus and Recording

EEG activity was recorded from 32 sites according to the international 10-20 system (Jasper, 1958) using a Quik-cap with silver/silver chloride (Ag/AgCl) electrodes and SynAmps 2 amplifiers. All electrode sites were referenced to linked mastoids and an AFz ground was used. Horizontal electro-oculographic (EOG) activity was recorded from electrodes placed at the outer canthi of both eyes, while vertical EOG activity was recorded from electrodes above and below the left eye. Electrode impedance was kept below 10KΩ and

EEG data were sampled at 1000Hz and amplified with a high-pass filter of 0.15Hz and low-pass filter of 100Hz. EEG data were merged with behavioural files and vertical and horizontal ocular artefact reduction was conducted using an algorithm developed by Compumedics Neuroscan (2006), based on combined regression analysis and artefact averaging (Semlitsch et al., 1986). Continuous data files were then low-pass filtered at 30Hz at 48dB per octave, epoched offline for a 1000ms epoch commencing 100ms before stimulus onset, and baseline corrected. High and low cut-offs for artefact rejections were set at 100µV and -100µV respectively. EEG activity corresponding to each instruction block was averaged and filtered with a high band pass of 0.15Hz and a low-pass of 30Hz.

In accordance with previous research and grand mean visual inspection, N1 and N2 were defined as the peak negativities within 50-150ms and 200-350ms post stimulus onset respectively over fronto-central electrodes (FC3, FCZ, FC4; Li et al., 2008). The P1 component, which indexes early sensory processing within the extrastriate visual cortex, was determined as the peak positivity within 60-120ms post stimulus onset over occipital electrodes (O1, OZ, O2; Olofsson et al., 2008). P3 was measured as the peak positivity within the 250-450ms time windows over parietal sites (P3, PZ, P4; O'Reilly et al., 2004). The LPP was determined as the mean positivity within 450-700ms post stimulus onset over parietal sites (P3, PZ, P4; Krug et al., 2000). As we investigated a number of ERP components and hypothesised differences in the level rather than speed of cortical processing, our analyses were limited to examining component amplitude rather than component latency. Our decision to exclude from analyses latency as an index of emotion regulation was in accordance with the Moser et al. (2010) study which we were extending in the present study by controlling for the impact of menstrual phase.

9.3.6. Design and Data Analysis

Separate univariate ANOVAs with Group as the between-subjects factor were conducted to assess any group differences in age, self-reported depressed mood, anxiety, and stress (as measured by the DASS), self-reported reappraisal and suppression emotion regulation strategies (as measured by the ERS), stimuli mean valence and arousal ratings (as measured by the picture viewing task), and self-reported perceived emotional distress and effort required when following Reappraisal, Suppression, and Maintain instructions (as measured by the post-task questionnaire).

Peak amplitudes of P1, N1, N2, and P3 and the mean amplitude of the LPP were analysed using 3[Group: Early Follicular, Midluteal, Men] × 2(Instruction: Reappraise, Maintain; *or* Suppression, Maintain) × 3(Site: FC3, FCZ, FC4; *or* P3, PZ, P4; *or* O1, OZ, O2) mixed factorial ANOVAs. Following the procedures of Goldin et al. (2008) and Moser et al. (2010), emotion regulation (reappraisal or suppression) and maintain instructions were included within the same task block. To rule out potential baseline differences between the maintain instructions in the Reappraisal and Suppression blocks, separate 3[Group: Early Follicular, Midluteal, Men] × 2(Instruction: Maintain (Reappraise), Maintain (Suppression)) × 3(Site: FC3, FCZ, FC4; *or* P3, PZ, P4; *or* O1, OZ, O2) mixed factorial ANOVAs were conducted for each ERP component.

Artefactual (e.g., evidence of visual or physiological artefact) electrode data values were replaced with the mean score of the surrounding electrodes. Three channels (FT7, FT8, FP2) were classified as artefactual for all participants, but these were not channels that were analysed. Outlier checking was conducted and data-points greater than three standard deviations above the mean were identified as outliers (Tabachnick & Fidell, 2013). To maintain the range and relative ordering of scores, outliers were replaced with a value .1 below this three standard deviation cutoff (Osborne & Overbay, 2004; Tabachnick & Fidell) and less than 1% of the data was replaced. Greenhouse-Geisser corrections were made where appropriate, significance levels were maintained at alpha <.05, and Sidak-corrected pairwise comparisons were used to test for significant differences between individual means and to control for multiple comparisons. Effect sizes measured using partial eta squared (ηp^2) and Cohen's *d* (Cohen, 1988) are reported for results involving Group differences to provide a clinically relevant effect size and to further control for multiple comparisons. Bonferroni correction was applied to control for multiple comparisons within correlational analyses. Data were analysed using the Statistical Package for the Social Sciences (SPSS; version 21). Obtained results involving electrode site were not reported unless involved in an interaction of hypothesised significance with Group or Instruction (see Appendix K for full ERP analyses summary; Appendix O).

9.4. Results

9.4.1. Salivary Progesterone

A univariate ANOVA demonstrated that women in the midluteal phase had significantly higher progesterone levels (*M*=195.04, *SD*=93.39, *Median*=177.50) than women in the early follicular phase (*M*=89.65, *SD*=91.92, *Median*=65.35), $F(2,81)=20.70$, *MSE*=6553.74, $p<.001$, $\eta p^2=.359$, $d=1.33$ [$H(1)=9.59$, $p=.002$][9].

9.4.2. Clinical and Demographic Data

No significant differences were found between men, early follicular women, and midluteal women in age, depressed mood, anxiety, stress, or emotion regulation strategies (*ps*>.05; see Table 1).

[9] Due to concerns of potential non-normality of salivary hormonal data, a non-parametric equivalent test (Kruskal-Wallis) was conducted to ensure any potential non-normality did not bias the results; this showed no contradictory results.

Table 1

Mean Age, Depression, Anxiety, and Stress Scores, Valence and Arousal Ratings, and Reappraisal and Suppression Emotion Regulation Strategies for Early Follicular Women, Midluteal Women, and Men

Variable	Early Follicular Women	Midluteal Women	Men	*F*	*p*	ηp^2
Age	23.54 (6.60)	23.45 (7.51)	24.41 (7.16)	.414	.66	.016
Depressed Mood	5.18 (8.71)	4.76 (6.44)	3.30 (3.45)	.616	.54	.015
Anxiety	3.64 (4.57)	4.84 (4.84)	2.85 (3.21)	1.20	.31	.029
Stress	8.11 (6.80)	8.14 (6.59)	6.04 (5.16)	1.023	.36	.025
Valence	1.97 (0.43)	1.76 (0.84)	2.97 (.57)	28.36	<.001	.412
Arousal	5.63 (1.28)	7.85 (1.27)	2.39 (1.34)	122.73	<.001	.752
Reappraisal	4.83 (1.02)	4.59 (1.08)	5.24 (1.34)	2.29	.11	.053
Suppression	3.19 (0.97)	3.24 (1.16)	3.64 (1.38)	1.20	.31	.029

Note. Standard Deviations in parentheses; No significant differences were found between participants in demographics; Early follicular and midluteal women both rated the unpleasant images as significantly more unpleasant and significantly more arousing relative to men, with midluteal women rating the images as significantly more arousing than the early follicular women; No significant differences were found between men, early follicular women, and midluteal women in trait emotion regulation strategy.

9.4.3. Picture Rating Task

Early follicular and midluteal women both rated the unpleasant images as significantly more unpleasant (early follicular: *d*=1.59; midluteal: *d*=1.94) and significantly more arousing (early follicular: *d*=2.52; midluteal: *d*=4.25) relative to men, with midluteal women rating the images as significantly more arousing than the early follicular women (*ps*<.001, *d*=1.72; see Table 1).

9.4.4. Post-task Manipulation Check

A review of the qualitative data from the post-task manipulation check questionnaire established that all participants were able to follow each emotion regulation instruction, with participants reporting similar Reappraise, Suppression or Maintain strategies. Specifically, all 84 participants reported the use of cognitive reappraisal to reduce their emotional response following the Reappraise instruction (e.g., "I told myself that the images were fake"). All 84 participants also reported reducing their emotional response following the Suppression instruction (e.g., "I internalised my emotions to reduce the emotional reaction I had to the images by not showing external indicators of how I was feeling"). All 84 participants were also able to successfully maintain their emotional responses to the Maintain instruction (e.g., "I viewed the image as I normally would and focused on the feelings naturally associated with the image").

Significant group effects revealed that both early follicular (*p*=.002, *d*=.89) and midluteal (*p*=.02, *d*=.64) women reported greater emotional distress than men when suppressing emotional response, however, midluteal women reported using more effort during suppression than men (p=.02, d=.67) and at trend level than early follicular women (p=.06, d=.51) (Table 2).

Table 2

Mean Scores for Emotional Distress and Effort, as Measured by the Post-task Manipulation Check, to Reappraisal, Suppression, and Maintain Instructions for Early Follicular Women, Midluteal Women, and Men

Variable	Early Follicular Women	Midluteal Women	Men	F	p	ηp^2
Distress (Maintain)	5.43 (1.0)	4.55 (1.24)	4.48 (1.01)	6.51	.002	.138
Distress (Reappraisal)	3.14 (.97)	3.52 (1.55)	2.89 (1.34)	1.63	.20	.039
Distress (Suppression)	5.07 (1.15)	4.72 (1.56)	3.85 (1.43)	5.58	.005	.121
Effort (Maintain)	4.14 (1.38)	4.03 (1.55)	4.37 (1.50)	.37	.69	.009
Effort (Reappraisal)	5.18 (1.54)	5.17 (1.61)	4.85 (1.38)	.42	.66	.010
Effort (Suppression)	4.68 (1.81)	5.45 (1.33)	4.44 (1.42)	3.33	.04	.076

Note. Standard Deviations in parentheses. Early follicular women reported significantly increased emotional intensity compared with both midluteal women and men when maintaining their emotional response. Early follicular and midluteal women reported significantly greater emotional intensity when suppressing their emotional response than men. Midluteal women demonstrated a trend towards utilising greater effort than early follicular women but reported significantly greater effort required relative to men when suppressing their emotional response.

9.4.5. Electrophysiological Data

Grand mean average waveforms for Reappraise/Maintain and Suppression/Maintain instructions according to Group at FC3, FCZ, and FC4 sites where the key finding was found are depicted in Figure 2.

9.4.5.1. Baseline Maintain (Reappraise) versus Maintain (Suppression) Instruction

A significant main effect of Instruction demonstrated that N2 amplitude was significantly greater to the Maintain (Suppression, *M*=-6.43, *SD*=.60) compared to the Maintain (Reappraise, *M*=-5.55, *SD*=.62) instruction, $F(1,81)=4.20$, $MSE=23.43$, $p=.04$, $\eta p^2=.049$. No other significant baseline differences were found for any ERP component.

9.4.5.2. Reappraise versus Maintain Instruction

P1: A significant main effect of Instruction showed that P1 amplitude was significantly greater to Reappraisal compared to the Maintain instruction, $F(1,81)=99.54$, $MSE=44.08$, $p<.001$, $\eta p^2=.551$. A significant effect of Group, $F(2,81)=3.21$, $MSE=37.85$, $p=.046$, $\eta p^2=.073$, was superseded by a Group × Site interaction, $F(3.74,81)=3.23$, $MSE=9.55$, $p=.016$, $\eta p^2=.074$. As shown in Figure 3, sidak post-hoc tests demonstrated that midluteal women had significantly greater P1 activity compared to men at O1 site ($p=.01$, $d=.83$), with activity also trending higher at O2 site ($p=.06$, $d=.63$). Whilst Figure 3 reveals that midluteal women had greater P1 amplitude than early follicular women, who in turn had greater P1 amplitude than men at occipital sites, these differences did not reach significance (*p* range=.26-1.0). No other significant main effects or interactions were found for P1 amplitude.

N1: As displayed in Figure 4, a significant main effect of Group, $F(2,81)=3.73$, $MSE=57.21$, $p=.03$, $\eta p^2=.084$, revealed that midluteal women had significantly greater N1 amplitude than men ($p=.02$, $d=.74$). While not reaching significance, midluteal women also had larger N1 amplitude relative to early follicular women ($p=.51$), who had larger N1 amplitude compared to men ($p=.38$). No other significant main effects or interactions for N1 amplitude were found.

N2 / P3 / LPP: No significant main effects or interactions were found for N2, P3, or LPP amplitudes.

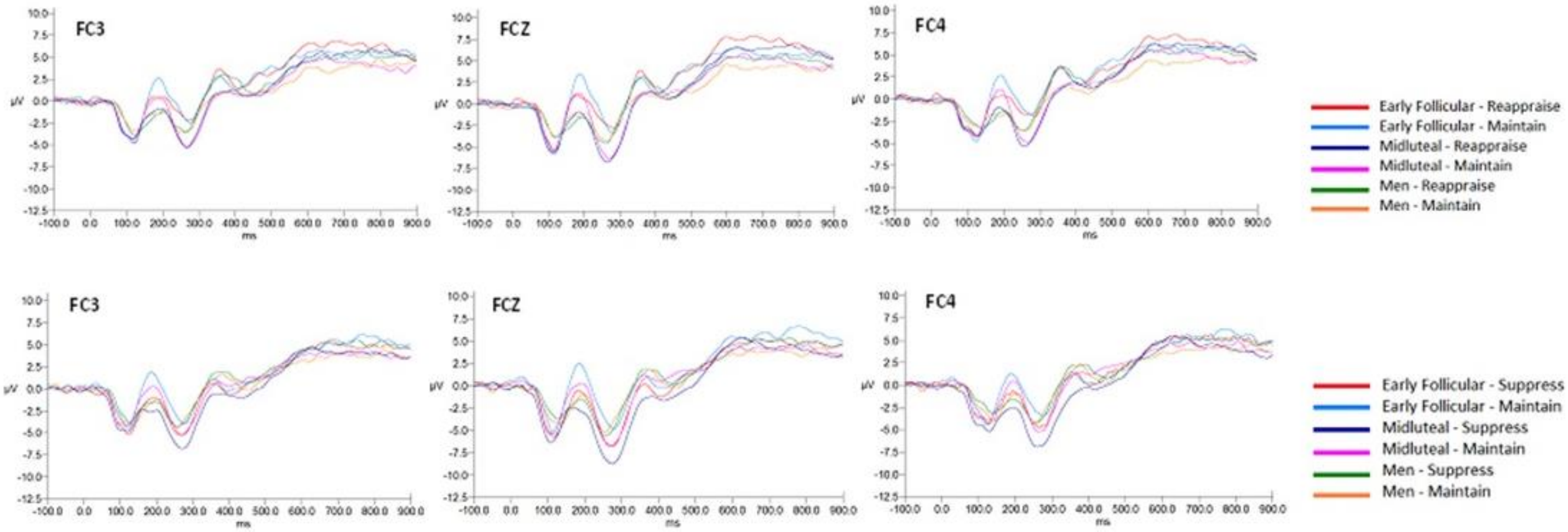

Figure 2. Grand mean average waveforms by Group in response to reappraisal/maintain and suppression/maintain instruction sets at FC3, FCZ, and FC4 sites where key N2 finding was found.

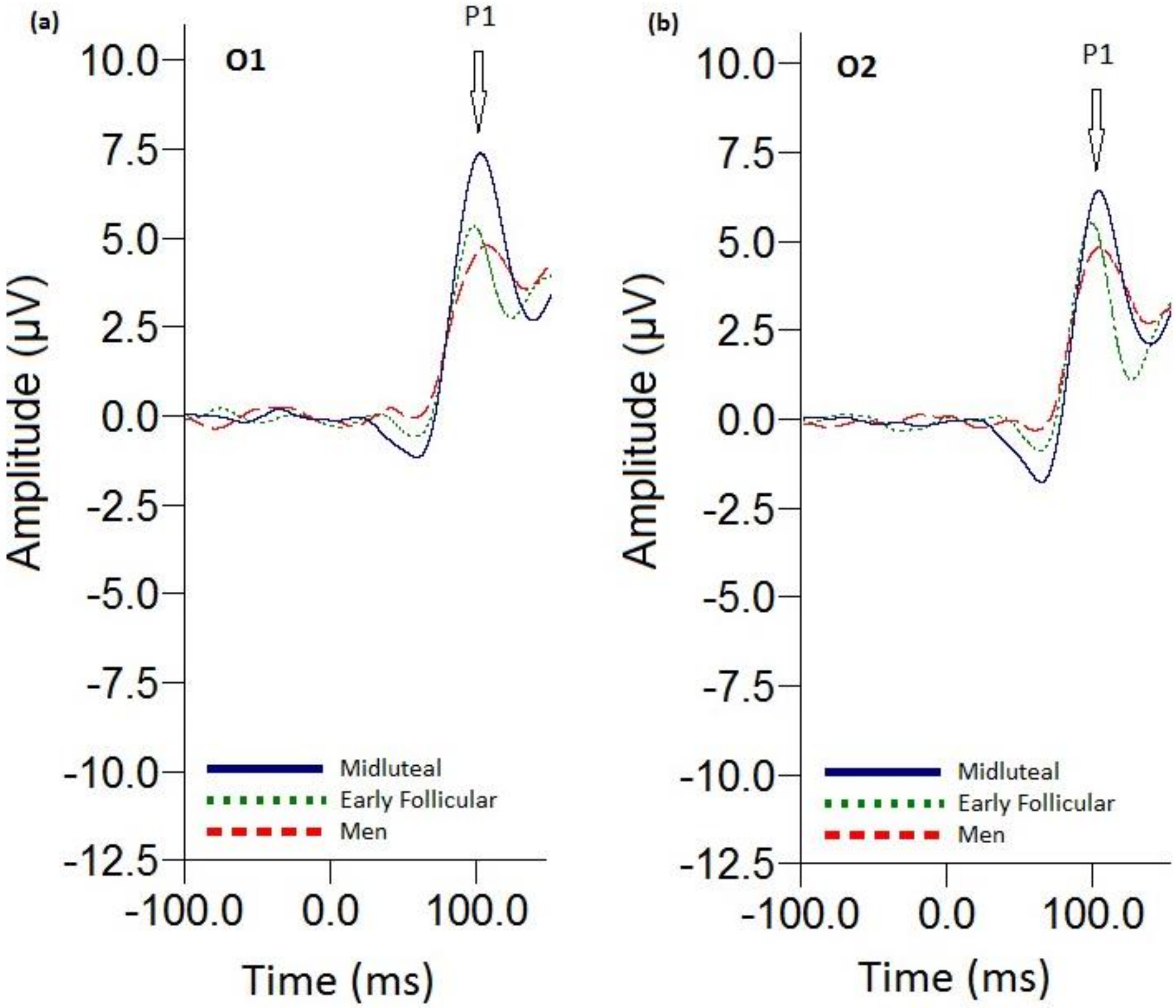

Figure 3. The Group × Site interaction for P1 amplitude at (a) O1 and (b) O2 site collapsed across reappraisal/maintain instruction set.

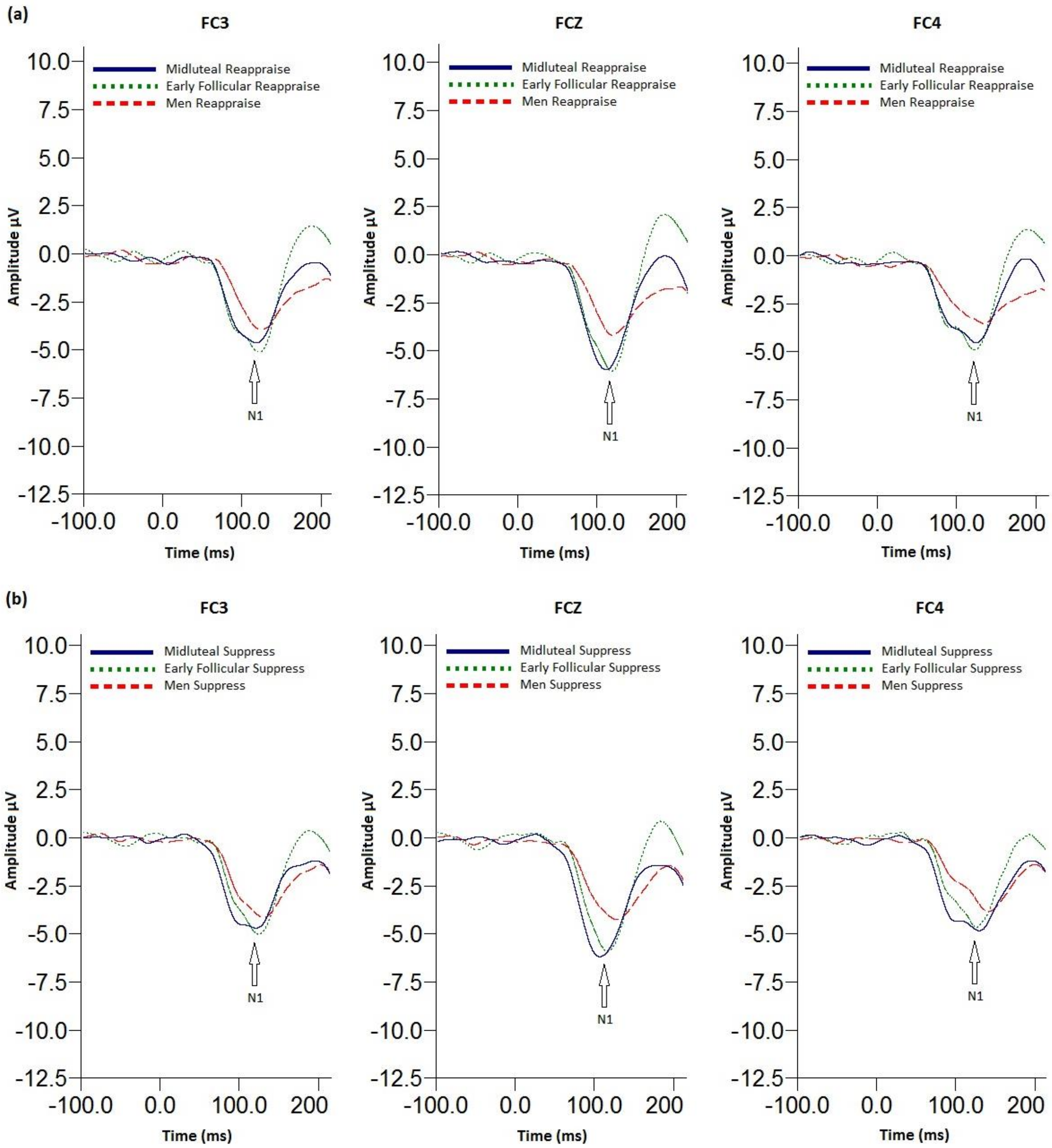

Figure 4. The Group main effect for N1 amplitude in response to (a) 'reappraisal' and (b) 'suppression' at FC3, FCZ, and FC4 sites.

9.4.5.3. Suppression versus Maintain Instruction

P1: A main effect of Instruction, $F(1,81)=113.29$, $MSE=42.88$, $p<.001$, $\eta p^2=.583$, demonstrated significantly greater P1 amplitude to Suppression compared with Maintain instruction. No other significant main effects or interactions for P1 amplitude were found.

N1: Sidak post-hoc tests investigating a trend towards a significant main effect of Group, $F(2,81)=2.83$, $MSE=74.35$, $p=.06$, $\eta p^2=.065$, showed midluteal women had larger N1 amplitude than men ($p=.06$, $d=.64$; see Figure. 3). Midluteal women had greater N1 amplitude than early follicular women ($p=.37$), who had greater amplitude than men ($p=.77$), however, these differences did not reach significance. No other significant main effects or interactions for N1 were found.

N2: A main effect of Instruction, $F(1,81)=17.54$, $MSE=12.68$, $p<.001$, $\eta p^2=.178$, showed N2 amplitude to be significantly greater to Suppression compared to Maintain instruction. As shown in Figure 5, there was a significant Group × Instruction interaction, $F(2,81)=3.35$, $MSE=178.70$, $p=.04$, $\eta p^2=.076$ for N2 amplitude. Sidak post-hoc analyses revealed that midluteal women had significantly greater N2 amplitude to the Suppression instruction than men ($p=.04$, $d=.69$). Midluteal women also showed greater N2 amplitude than early follicular women ($p=.46$), who showed greater N2 amplitude relative to men ($p=.55$), however, these differences did not reach significance. No other significant main effects or interactions for N2 amplitude were found.

P3: A significant main effect of Instruction, $F(1,81)=4.39$, $MSE=15.31$, $p=.04$, $\eta p^2=.051$, showed P3 amplitude to be significantly lower to Suppression than Maintain instruction. No other significant main effects or interactions for P3 amplitude were found.

LPP: No significant main effects or interactions were found for LPP amplitude.

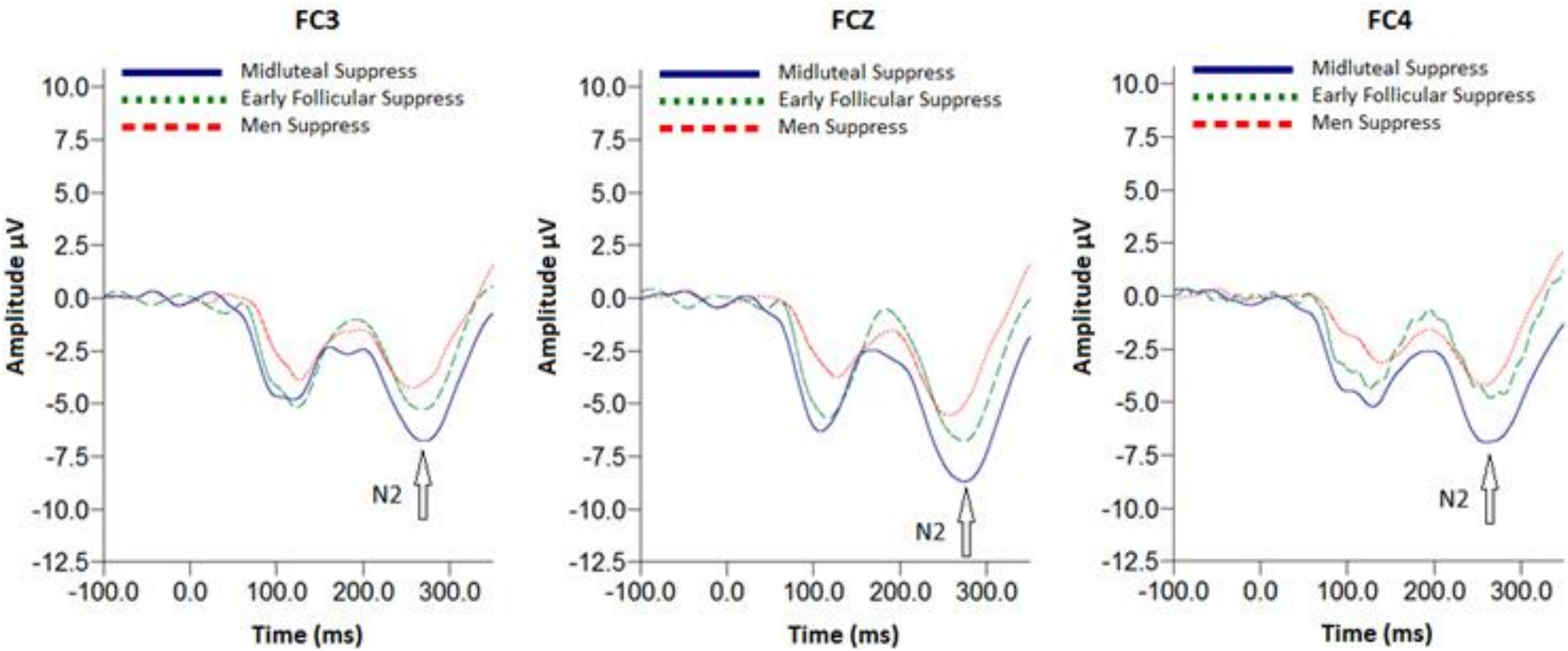

Figure 5. The Group × Instruction interaction for N2 amplitude for early follicular, midluteal women, and men in response to ‘suppress’ at FC3, FCZ, and FC4 sites.

9.4.5.4. Relationship between Progesterone or Anxiety (DASS) and ERP Components

Pearson's product-moment coefficients (Pearson's *r*) were conducted to examine the relationship between anxiety levels (as measured by the DASS) and the ERP components collapsed across their respective sites. To follow-up the significant 'Group' effects specifically, planned correlations between progesterone and the relevant ERP components collapsed across their respective sites were also performed using Pearson's product-moment coefficients.

When anxiety level and ERP component amplitude was correlated we did see a significant negative correlation between anxiety and N1 during suppression which indicated that as anxiety level increased N1 amplitude also increased. A significant negative correlation was also found between anxiety and P3 during suppression showing that as P3 amplitude decreased as anxiety levels increase. However, neither of these correlations were significant or at trend level following Bonferroni correction (Appendix N).

As shown in Appendix N, while no relationship was found between progesterone and P1 amplitude during suppression, there was a trend for a positive correlation between progesterone and P1 amplitude during reappraisal indicating that P1 amplitude during reappraisal increased as progesterone levels increased. There was a significant negative correlation between progesterone and N1 amplitude during both reappraisal and suppression showing that as progesterone levels increased, N1 amplitude also increased during reappraisal and suppression. Whereas no significant relationship was found between progesterone and N2 amplitude during reappraisal, a significant negative correlation between progesterone and N2 amplitude during suppression revealed a relationship between increased progesterone levels and increased N2 amplitude (see Table 3). Overall, progesterone was significantly correlated with ERP amplitudes of the effects where we observed ‘Group’ differences. This suggests a direct role of progesterone in influencing the obtained ‘Group’ findings, however, it should be noted that these effects were of small magnitude and should be considered as trends as they would not remain significant following Bonferroni correction.

9.4.5.5. Relationship between Emotion Reactivity and Emotion Regulation

As reported in Appendix N, to further explore the proposed relationship between early emotional reactivity and later emotion regulation in Study 3 we conducted Pearson product-moment correlations between the ERP components collapsed across their relevant sites. More specifically, early ERP indices reflecting emotional reactivity (P1, N1) were correlated with later ERP components reflecting emotion regulation processes (P3, LPP) separately for early follicular women, midluteal women, and for men. If emotion regulation (reappraisal or suppression) strategies were effective, we expected reduced P3 and LPP amplitudes during emotion regulation instruction. If the hypothesis that greater emotional reactivity impairs later emotion regulation is supported, we would expect a positive correlation between early P1 and later P3/LPP amplitudes, such that increases in P1 amplitude (reflecting enhanced emotional reactivity) are associated with greater emotional processing (P3/LPP amplitude) despite instructions to down-regulate emotional response. In contrast, for N1 amplitude we would predict a negative correlation between increased N1 amplitude (reflecting enhanced reactivity) and increased P3/LPP amplitude if there was impaired emotion regulation associated with greater emotional reactivity, as greater emotional reactivity for N1 is indexed by increased negative amplitude.

We applied Bonferroni corrections to adjust for eight comparisons prior to interpretation of the correlations which resulted in a *p*-value of .006, and we would thus argue that a *p*-value less than .01 reflects a trend level correlation. Following Bonferroni adjustment, we only found two correlations at significant or trend levels when examining the relationship between early reactivity and later emotion regulation. While we particularly expected women, especially midluteal women, to demonstrate an association between emotional reactivity and deficits in later emotion regulation, both of the correlations were revealed for men rather than in women. For men, a moderate, negative correlation approaching significance was revealed between N1 and P3 during reappraisal (r=-.51, p=.007, Figure 6) while a significant strong, negative correlation was demonstrated between N1 and LPP during reappraisal (r=-.65, p<.001, Figure 7). These correlations indicated that for men as N1 increased, signifying greater emotional reactivity, P3 and LPP amplitudes also increased, signalling poorer suppression ability.

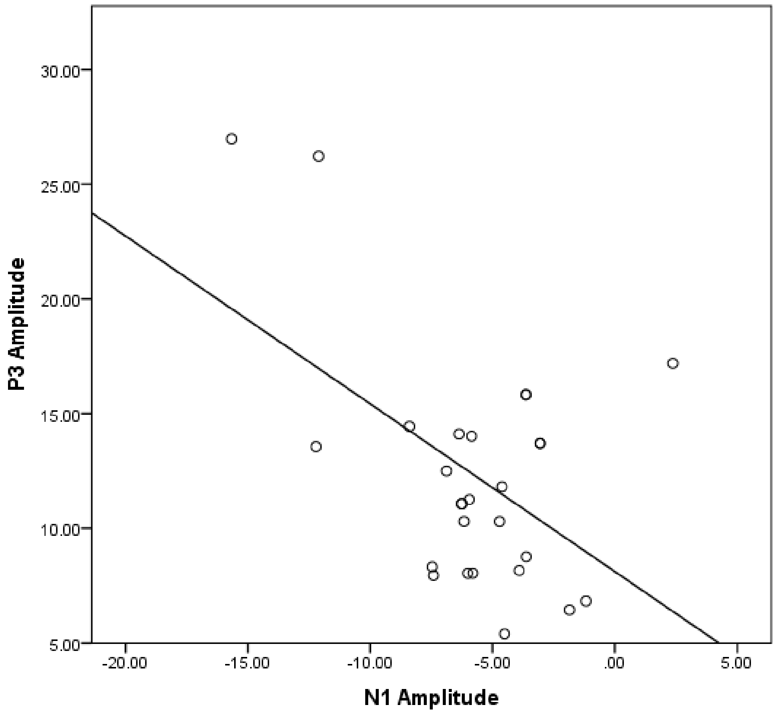

Figure 6. Scatterplot of relationship between the N1 and P3 components during reappraisal for men. *Note.* N1 collapsed across FC3, FCZ, FC4 sites and P3 collapsed across P3, PZ, P4 sites.

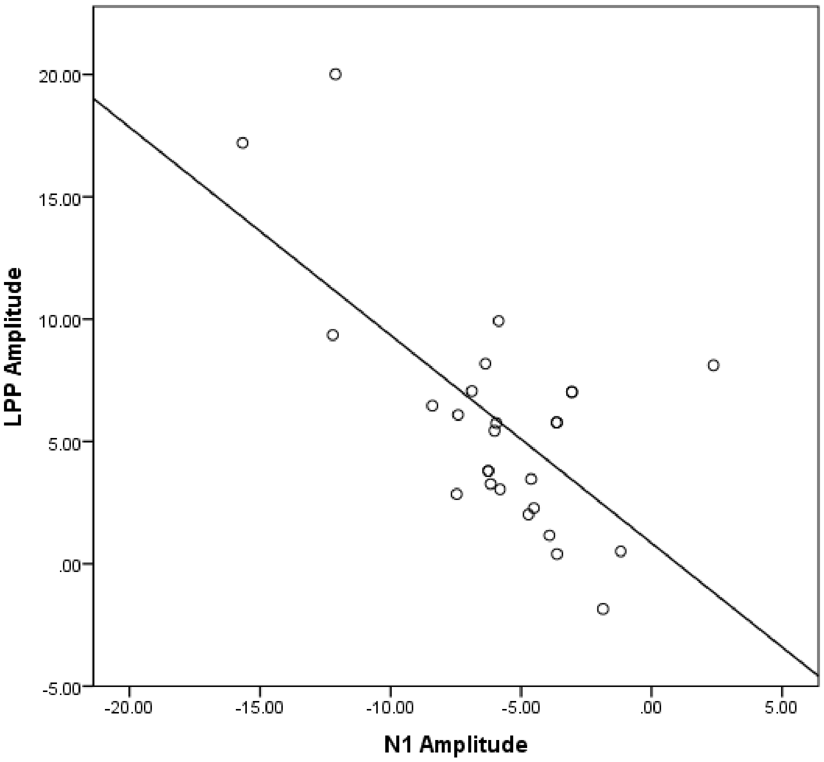

Figure 7. Scatterplot of relationship between the N1 and LPP components during reappraisal for men. *Note.* N1 collapsed across FC3, FCZ, FC4 sites and LPP collapsed across P3, PZ, P4 sites.

9.5. Discussion

This study examined the impact of menstrual cycle phase on early emotional reactivity and later emotion regulation processing using ERPs, by comparing women in the midluteal phase with women in the early follicular phase and men whilst completing an emotion regulation task. As expected, women relative to men displayed an early attentional bias reflected in greater P1 and N1 amplitude to unpleasant stimuli, and midluteal women in particular displayed greater early ERP amplitudes compared to early follicular women and men. A novel finding was that midluteal women exhibited greater difficulty in suppressing negative emotional stimuli relative to men reflected in elevated N2 amplitude to unpleasant stimuli during suppression instruction. The level of emotional distress experienced during suppression revealed a group effect in that both early follicular and midluteal women experienced greater distress compared to men. However, complementing the N2 finding, the level of effort required when suppressing the emotional response to the stimuli demonstrated a menstrual phase effect, with midluteal women utilising greater effort than early follicular women, and significantly greater effort than men. These findings are consistent with the proposed mechanism of women having difficulty regulating their emotional responses to unpleasant stimuli and/or emotional states underlying the greater prevelance of anxiety disorders in women relative to men, with this study revealing the necessity of menstrual phase to be considered.

9.5.1. Early Preconscious Emotional Reactivity: P1 and N1

Relative to men, both early follicular and midluteal women were shown to have increased early cortical activity, with midluteal women demonstrating significantly greater reactivity than men. More specifically, when instructed to reappraise their emotional response to unpleasant stimuli, midluteal women had significantly greater P1 amplitude compared to men. Early follicular women also had higher P1 amplitude than men, but this difference did not reach significance. Of particular importance was that this female processing bias was modulated by menstrual phase as midluteal women showed significantly higher P1 activity over occipital sites compared to men (Figure 3).

The observed P1/N1 findings in the current study support previous research which demonstrated midluteal women to have enhanced generalised early visual processing (Lusk et al., 2015), from a study using the same participants but a different visual processing (rather than emotion regulation) task. As P1 activation at occipital region indexes early automatic visual attention (Hillyard & Anllo-Vento, 1998; Luck et al., 2000), the finding of increased P1 for midluteal women relative to men provides electrophysiological evidence that midluteal women display greater early preconscious processing of visual emotional stimuli. As was the case for Study 2, the present P1/N1 findings are consistent with evidence associating the midluteal phase with enhanced visual processing (Avitabile et al., 2007; Wassell et al., 2015a, 2015b) and with previous findings of high progesterone levels (as observed in midluteal women) being associated with greater visual selective attention capacity (Solis-Ortiz & Corsi-Cabrera, 2008), improved visual perception (Wijayanto et al., 2009), and greater visual memory (Phillips & Sherwin, 1992). As discussed previously, the observed early processing findings are in accordance with the body of fMRI literature demonstrating a connection between the amygdala and occiptital regions during visual processing (de Kloet et al., 2005) and greater amygdala activation to unpleasant emotional stimuli in midluteal women (Andreano et al., 2014; Bayer et al., 2014; Costafreda, Brammer, David, & Fu, 2008; Gingnell et al., 2012; Kober, Barrett, Joseph, Bliss-Moreau, Lindquist, & Wager, 2008; Sergerie, Chocol, & Armony, 2008). Given this concordance with previous neuroimaging literature, there is a need for continued electrophysiological investigation of the impact of menstrual phase on visual emotion processing.

There was a significant group main effect for the N1 ERP component in the reappraisal block which showed that midluteal women had significantly greater N1 amplitudes than men. This group effect was also present in the suppression block but only reached trend level (Figure 4). Midluteal women had larger N1 amplitudes than early follicular women, who had larger N1 amplitudes than men, but these differences did not reach significance. As N1 indexes early preconscious allocation of attention (Dong et al., 2011; Olofsson et al., 2008), these findings suggest that women, particularly midluteal women, display increased automatic activity in frontal attention networks compared to men. As the initial attentional response was to emotional stimuli, this increased early emotional reactivity in females is consistent with previous ERP studies reporting increased N1 to emotional stimuli in females (e.g., Li et al., 2008; Lithari et al., 2010; Gardener et al., 2013).

As reported above, Pearson product-moment correlations between the ERP indices of early emotional reactivity (P1, N1) and later emotion regulation (P3, LPP) were conducted to further examine the relationship between emotional reactivity and later emotion regulation on cortical activity. Negative correlations between N1 and P3 and N1 and LPP were demonstrated for men, and were consistent with predictions of the process-specific timing hypothesis (Sheppes & Gross, 2011) that early emotional reactivity would impair later emotion regulation capacity. These correlations suggested that as N1 increased (reflecting greater emotional reactivity), P3 and LPP amplitudes also increased during reappraisal instructions, signalling reduced suppression capacity in men. It is interesting that these correlations were seen only in men rather than in women as would be anticipated. These findings however should be interpreted with caution as the large individual variability in ERP responses may have confounded the correlational data and this is a novel finding which requires replication.

9.5.2. Early Conscious Attention: N2

This study demonstrated a novel finding of a differential N2 amplitude response to suppression across menstrual phase. N2 activation was significantly increased during suppression of emotional response for midluteal women compared to men (Figure 5). While N2 amplitude for midluteal women was greater than for early follicular women, who showed greater amplitude than men, these effects failed to reach significance. Within visual processing paradigms, the N2 has been associated with selective attention and is thought to index early conscious allocation of attention to emotional stimuli (Anderson & Stanford, 2012; Balconi & Lucchiari, 2007; Patel & Azzam, 2005; Schupp et al., 2006). The finding of increased N2 amplitude in midluteal women compared to men when suppressing emotional responses indicates that women in the midluteal phase require greater cortical processing when consciously suppressing their emotional responses to unpleasant stimuli compared to men, which may reflect impaired suppression capacity. This interpretation is supported by the correlational data showing a relationship between increased progesterone levels, as observed during the midluteal phase, and increased N2 amplitude during suppression but not reappraisal. This interpretation is further supported by the behavioural rating data, where midluteal women reported greater effort during suppression than both early follicular women and men. Interestingly, previous ERP literature has associated increased N2 amplitude with increased effort (e.g., Go/Nogo tasks, Benikos et al., 2013). The finding that midluteal women require greater cortical processing and effort when suppressing their emotional response compared to men converges with recent evidence from fMRI studies suggesting that men have superior and more efficient suppression ability than women (McRae et al., 2008). These consistent behavioural rating and N2 amplitude findings suggest that women, particularly midluteal women, may have a reduced capacity to suppress negative emotional processing. Further research should investigate similarities in sex differences in clinical anxiety disorder populations.

9.5.3. Conscious Emotion Regulation: P3 and LPP

The only observed emotion regulation effect during late processing was reduced P3 amplitude during suppression of emotional response which suggest that irrespective of group, suppression was an effective strategy to reduce emotional response to the unpleasant stimuli. While menstrual phase modulation was found during early preconscious and early conscious processing, no sex or menstrual phase effects during late conscious emotional regulation processing were demonstrated in the current study.

Several studies examining emotion regulation instructions with ERPs have revealed an effect of emotion regulation instruction on the LPP (e.g., Hajcak & Nieuwenhuis, 2006; Hajcak et al., 2010; Moser et al., 2010). However emotion regulation modulation of the LPP was not observed in the current study and methodological differences may have influenced the divergent findings given previous research has superimposed emotion regulation instructions over a cognitive task (e.g., Moser et al.) or failed to examine menstrual phase (e.g., Hajcak & Nieuwenhuis.). In addition, previous studies reporting an impact of menstrual phase on LPP amplitudes found inconsistent results, with some reporting increased LPP amplitude to sexual stimuli during the late follicular phase compared to early follicular and midluteal phases (Krug et al., 2000) and others reporting increased LPP amplitudes to all emotional and neutral stimuli in midluteal women compared to early follicular (Zhang et al., 2013). To the best of our knowledge, this is the first emotion regulation study to assess the impact of menstrual phase using ERPs, and consequently the comparison of the current study with previous literature is somewhat limited.

9.5.4. Limitations and Future Research

Whilst this study addresses an important unresolved area in the sex differences and emotion literature, and reveals novel ERP evidence that midluteal women are less able to regulate their emotional response through suppression than men, there are some limitations to this study. The current task was adapted from those of Goldin et al. (2008) and Moser et al. (2010), and thus reappraisal and suppression strategies were compared against their own baseline (maintain instruction) thereby restricting us from directly comparing the effects of reappraisal and suppression strategy on cortical activity. To minimise confounding of reappraisal and suppression, future emotion regulation research should include separate reappraisal, suppression, and maintain blocks to enable direct comparison. We analysed for potential baseline differences between the reappraisal and suppression maintain blocks for each ERP component and found that maintain (suppress) was higher than maintain (reappraise) for N2 amplitude. However, no baseline differences involving group or sex were found. Given the few baseline differences and that the greater N2 amplitude for women than for men during suppression is in the opposite direction, this difference therefore did not inflate our findings.

While we failed to replicate P3 and LPP modulation reported in previous emotion regulation studies (e.g., Hajcak & Nieuwenhuis., 2006; Hajcak et al., 2010; Moser et al., 2010), these studies did not examine menstrual phase which may explain why an emotion regulation effect was not found in the current study. Due to restrictions on recruiting a longitudinal sample, we used a between-group design and collected a relatively small cross-sectional participant sample. While analyses were adequately powered, this may have resulted in an underestimation of differences between menstrual phases because of inter-individual variability between groups. Future research would benefit from using a within-group design with a larger sample to assess women tested across their different menstrual phases to control for inter- and intra- individual differences.

Unfortunately, the estradiol data in this study could not be analysed due to artefact; while standardised storage and assay protocols were followed, data collection occurred over a 12-month period, which may have led to deterioration in saliva samples that impacted on estradiol values. Thus, we were unable to examine if the effects are due specifically to estradiol or progesterone. Future research should strive to collect blood samples for more reliable estimates of estradiol and examine the impact of estradiol and progesterone on ERPs, specifically.

9.5.5. Conclusion

Previous emotion regulation studies have not investigated sex hormones or the impact of menstrual phase on emotion regulation processing. The current study provides novel evidence that menstrual phase impacts on cortical processing during suppression of negative emotional responses. Specifically, midluteal women revealed increased N2 amplitude following suppression instruction and reported greater effort when suppressing compared to men, suggesting they have less capacity to suppress cortical processing of unpleasant stimuli relative to men. In addition, midluteal women reported greater early automatic attentional processing of negative emotional stimuli. This reduced capacity in women to suppress negative emotional processing is in line with the proposed mechanism of poorer emotion regulation capacity involved in the greater female risk of anxiety, and indeed suggests that impaired suppression capacity may be a potential risk factor for developing anxiety disorders that are more prevalent in women,. Further, the finding that this is particularly significant during the midluteal phase indicates that women may have heightened risk of emotional dysregulation in the later stages of their menstrual cycle. The current findings highlight the importance of considering menstrual phase in emotional neuroscience research when examining visual processing and emotion regulation. Future research should examine the relative impact of progesterone and estradiol in influencing these processes.

9.6. Acknowledgements

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CHAPTER 10: GENERAL DISCUSSION

10.1. Summary of Key Findings

The primary aim of this program of research was to investigate the effect of sex and menstrual phase in the cortical processing of emotion and emotion regulation. The key findings from the three studies informing this thesis will be summarised and integrated below (for a visual representation of the major thesis findings please refer to Appendix A).

The competing motivational and negativity bias hypothesis models were investigated in Study 1 with ERPs recorded while participants completed a dual-oddball task. The only important behavioural result obtained indicated that women rated the unpleasant stimuli as being significantly more arousing than men which is consistent with the predictions of the negativity bias. However, ERP data did not clearly support either model; there was no evidence for the negativity bias hypothesis, but some evidence in later components was in line with the motivational model.

Whereas women displayed larger N2 amplitudes to neutral and unpleasant stimuli compared with pleasant stimuli, men exhibited greater N2 amplitude to neutral compared to both pleasant and unpleasant stimuli, with unpleasant stimuli found to elicit larger amplitude than pleasant stimuli. In contrast, P3 amplitude was shown to be greater to pleasant and unpleasant stimuli relative to neutral stimuli regardless of sex. Similar to the P3 component, LPP amplitudes were found to be greater to the emotional (pleasant and unpleasant) relative to neutral stimuli for women and men during completion of the dual-task condition, with LPP amplitudes to all valences shown to be significantly enhanced in women as compared to men. Taken together, this pattern of data was unclear and deviated somewhat to previous literature, and this divergence may have reflected critical confounds that were not controlled in Study 1 such as the impact of menstrual phase and the inclusion of sexual stimuli in the study design.

Study 2 extended Study 1 to test the competing motivational and negativity bias models whilst controlling for menstrual phase, and whilst matching the valence and arousal levels of stimuli. ERPs were recorded while men and women in the early follicular (day 1-7 (low estradiol/low progesterone)) and midluteal (day 18-24 (high estradiol/high progesterone)) phases of the menstrual cycle completed a passive viewing task containing neutral, and low- and high- arousing pleasant and unpleasant stimuli.

In line with the negativity bias hypothesis, early follicular and midluteal women both rated the low- and high- arousing unpleasant stimuli as more unpleasant and/or more arousing than did men, while no behavioural support for the motivational model was found. Revealing a significant effect of midluteal menstrual phase in early visual processing, midluteal women exhibited significantly enhanced P1 amplitude at occipital regions to all visual stimuli relative to men. Similarly, midluteal women exhibited greater N1 amplitudes than men to all the visual stimuli. In contrast, no sex or menstrual phase differences were observed in later (N2, P3, LPP) processing. However, consistent with the negativity bias hypothesis, condition main effects revealed enhanced P3 and LPP amplitudes to highly-arousing unpleasant stimuli relative to the other stimuli conditions.

The results of Study 2 demonstrate that women have greater early automatic visual processing than men, and this effect was shown to be markedly stronger in midluteal women at the earliest stage of preconscious visual processing. However, this finding was found across all emotional and neutral stimuli, which does not signify emotion modulation or confirm predictions of either the motivational model or negativity bias hypothesis. Rather, this finding is indicative of generalised enhancement of visual processing in women when sex hormones are elevated during the midluteal menstrual phase. Study 2 emphasised the necessity for menstrual phase to be considered when sex differences in the cortical processing of visual emotional stimuli are investigated.

A recent theoretical model (‘process-specific timing hypothesis’) stipulates that early enhanced emotional reactivity impairs later emotion regulation processes (Sheppes & Gross, 2011). Accordingly, ERPs were recorded in Study 3 while men and women in the early follicular and midluteal phases of the menstrual cycle completed an emotion regulation task to investigate sex differences in cortical activity during early emotional reactivity and later emotion regulation processes controlling for menstrual phase. During suppression, a novel finding of enhanced N2 amplitude for midluteal women relative to men was revealed, which is argued to indicate that midluteal women are significantly less able than men to suppress cortical processing of unpleasant stimuli. This interpretation was supported by the obtained behavioural ratings data which showed that while both early follicular and midluteal women reported more distress than men, midluteal women also reported more effort than men when attempting to suppress their emotional responses.

Although we only used unpleasant stimuli which limits us from saying our results definitively support a negativity bias, consistent with the predicted negativity bias effect during early visual processing, midluteal women showed enhanced unconscious cortical (P1/N1) reactivity relative to men in Study 3 regardless of instructional set, with this result reflecting greater early attentional processing. However, inconsistent with predictions, this sensitivity did not influence later conscious (P3, LPP) emotion regulation processes, and anticipated sex or menstrual phase effects during emotion regulation processing were not observed. The findings of Study 3 demonstrated that women in the midluteal phase have difficulty down-regulating their behavioural and early conscious cortical responses to unpleasant stimuli during suppression, which indicates that early reactivity in midluteal women may be related to difficulties with suppressing emotional responses. Consistent with the findings of Study 2, the outcomes of Study 3 further highlight the importance of considering the impact of menstrual phase when investigating sex differences in the cortical processing of emotional reactivity and emotion regulation.

When taken together, the findings of the three studies provided consistent behavioural evidence of a negativity bias in women (which was not strongly modulated by menstrual phase). This evidence concurs with previous studies which have similarly reported sex and emotion modulation in behavioural but not ERP responses (e.g., Kim et al., 2013; Syrjanan & Wiens, 2013). In contrast, ERP data across the studies did not provide clear evidence of greater reactivity to unpleasant stimuli in women (regardless of menstrual phase) compared to men, or to emotional stimuli in women compared to men. Instead, when controlling for menstrual phase, there was evidence that women in the midluteal phase displayed greater early visual processing and reactivity to all stimuli (including neutral stimuli), suggesting a generalised enhancement of visual processing in women in the midluteal phase. This accords with recent evidence associating high levels of progesterone with improved visual processing and visual memory (e.g., Wassell et al., 2015a, 2015b).

Finally, Study 3 revealed that midluteal women displayed both enhanced early visual reactivity to stimuli as well as increased mid-latency cortical processing during attempts to suppress responses to unpleasant emotional stimuli. This was accompanied by increased self-reports of effort and distress during suppression in the midluteal women compared to the other groups, which may be interpreted to reflect greater difficulty in suppressing negative emotional responses. Research (e.g., Aldao, Nolen-Hoeksema, & Schweizer, 2010; Etkin & Wager, 2007; Hofmann et al., 2012; Jackson et al., 2000; Webb et al., 2012) has demonstrated that suppression can lead to paradoxical increases in negative affect and physiological arousal as compared to reappraisal which has been shown to bring about reductions in physiological, subjective, psychological, and cortical responding. Further, as will be discussed below, anxiety and mood disturbance is experienced more often and at greater severity during the midluteal menstrual phase compared with other menstrual cycle phases (Cockerill et al., 1994; Epperson & Hantsoo, 2014; Freeman, DeRubeis, & Rickels, 1996; McLean & Anderson, 2009; Schwartz, Romans, Meiyappen, De Souza, & Einstein, 2012; Sundström Poromaa & Gingnell, 2014; Van Goozen, Wiegant, Endert, Helmond, & Van de Poll, 1997). We therefore suggest that impaired emotion regulation capacity in midluteal women was specific to suppression relative to reappraisal as suppression is associated with psychopathology more so than reappraisal and psychopathology is more commonly experienced during the midluteal cycle of the menstrual phase. Such suppression difficulties are therefore highly suggestive of a greater risk of emotional dysregulation in women in the midluteal phase of their menstrual cycle.

In the introductory chapters of this thesis, several potential mechanisms were proposed to underlie the greater prevalence of anxiety in women relative to men. One suggested mechanism was that women have greater emotional reactivity, and we questioned whether this reactivity was specific to unpleasant stimuli or to emotional stimuli in general. Alternatively, either in addition to greater reactivity, or as a separate mechanism, we suggested that women may be less able to regulate their emotional responses to unpleasant stimuli as compared to men. Evidence from Studies 2 and 3 suggest both mechanisms may be at play. However, an important qualification is nuanced. Study 2 revealed that rather than a specific negativity bias or a greater processing of emotional stimuli in general, there was a generalised increase in processing all visual stimuli. Study 3 revealed there was greater cortical processing in suppressing unpleasant stimuli, coupled with greater effort and distress during suppression suggesting impaired capacity to regulate unpleasant emotions. However, critically both studies revealed this was modulated by menstrual phase, with women in the midluteal menstrual phase displaying the most marked pattern.

Overall, the program of studies outlined in this thesis, particularly the obtained electrophysiological evidence thus underscore the importance of controlling for the powerful influence of menstrual phase when investigating sex differences in emotion and visual processing. This is primarily because emotional reactivity and dysregulation difficulties are implicated in anxiety disorders which are more prevalent in women, and particularly as anxiety has been shown to be elevated during the midluteal phase of the menstrual cycle when sex hormone levels are elevated (Aldao et al., 2010; Gross & Jazaieri, 2014; McLean & Anderson, 2009; Nolen-Hoeksema, 2012).

10.2. General Emotion Processing: Motivational Model or Negativity Bias?

We assessed the emotion processing ERP data collapsed across sex in order to examine whether any support for the motivational model or negativity bias was observed in Studies 1 and 2 without considering sex differences (see Appendix O). When valence effects were considered collapsed across women and men we found no evidence of response enhancement specficially to unpleasant stimuli (negativity bias) or to unpleasant and pleasant stimuli relative to neutral stimuli (motivational model) in P1 or N1 in either Study 1 or Study 2. This suggests that the impact of a dual-task and of cognitive load did not influence early ERP components. However, this finding does contradict predictions of the negativity hypothesis which would argue that unpleasant stimuli are rapidly processed with increased emotional reactivity (Ito & Capcioppo, 2005).

The lack of early P1/N1 reactivity in Study 1 and Study 2 is somewhat divergent to recent ERP findings and this may be due to methodological differences. A key possibility is the impact of fatigue as task duration was relatively long given that the duration of the dual- and passive viewing tasks were ten and sixteen minutes respectively whereas previous studies reporting a negativity bias in women have often used tasks with a shorter duration (e.g., five minute task duration, Lithari et al., 2010). While similar stimulus durations were used (i.e,. 1000ms), the length of the current tasks were longer than previous literature as we doubled the number of stimuli in each task to ensure excellent signal to noise, but this may have inadvertently led to habituation of the P1 and N1 components. Thus, task duration may have impacted on initial reactivity to stimuli as arousal has been shown to modulate P1 and N1 (Feng et al., 2014; Luck, 2014). Task length and fatigue may have also impacted responsiveness to the task stimuli as a consequence of the dual- and passive viewing tasks being completed in a single block rather than in shorter blocks separated by a rest period, as rest breaks have been shown to increase attentional engagement with stimuli and to effectively reduce fatigue (Lim & Kwok, 2016).

Evidence for the motivational model, reflected by larger P3 and LPP amplitudes to pleasant and unpleasant compared to neutral stimuli, were found in Study 1 with cognitive load, but conversely evidence for a negativity bias during late conscious processing (greater P3 and LPP to unpleasant stimuli specifically) was evident in Study 2 when the female groups were examined separately. Similarly, evidence for the negativity bias was revealed when early follicular and midluteal women were averaged together, as LPP amplitude was shown to be greater to highly arousing unpleasant stimuli compared to men. Such a finding indicates that increased cognitive load with the dual-task paradigm might influence later ERP (P3 and LPP) components more so than early components. This finding also suggests that perhaps the salience and heightened processing of unpleasant stimuli in Study 1 was minimised due to the competing cognitive demands in the dual-task paradigm, leading to a generalised increase to pleasant and unpleasant compared to neutral stimuli, but not a specific increase to neutral stimuli. That is, the dual-task in Study 1 may have occupied more processing resources than the passive viewing task in Study 2 which consequently constrained responses to unpleasant stimuli and led to blunting of a negativity bias in Study 1. This may have been due to enhanced attention to, and cognitive processing of, pleasant and unpleasant stimuli in the context of having an embedded attentional task. However, while LPP amplitudes to pleasant and unpleasant stimuli were larger compared to neutral stimuli during the dual-task condition irrespective of sex, this interpretation should be regarded with caution as there were no clear single- versus dual- condition effects in P3 amplitude within Study 1.

Unconscious perception has been shown to modulate neural activity within 100-200 milliseconds following stimulus onset but, beyond this window, there is a rapid decay in activity (Bernat et al., 2001; Kiefer and Spitzer, 2000; Marzi et al., 2000). A growing number of studies have been conducted in recent years showing that emotional stimuli (emotionally expressive faces) can be processed without conscious awareness. Supporting evidence for the unconscious evaluation of emotional stimuli however remains mixed. Good evidence comes from patients who have lost their primary visual cortex but maintain the ability to process emotional expressions presented in the visual modality despite being unable to consciously report the stimuli (i.e., ‘affective blindsight’; de Gelder et al., 1999; Pegna et al., 2005), together with emotion selective responses in subcortical limbic structures (Vuilleumier et al. 2002; Pegna et al.). More specifically, evidence from these patients suggests that the amygdala processes these stimuli through a direct colliculopulvinoamygdalar route (Morris et al., 2001), although additional pathways involving projections from subcortical regions to the extrastriate cortex may also be possible (e.g., Gonzalez-Andino et al., 2009; for a recent review see Tamietto and de Gelder, 2010).

Unconsious emotion processing has been investigated in healthy participants using using studies where subjective awareness of an emotionally expressive face is disrupted by backward masking paradigms in which a briefly presented target face is masked by the subsequent presentation of a second stimuli (usually a neutral face), which prevents the target image reaching conscious awareness (Esteves & Ohman 1993). This empirical design has commonly been used in fMRI experiments which have demonstrated that the amygdala responds to emotional expressions even when they are not consciously detected (e.g., Morris et al., 1998, 1999; Whalen et al., 1998; Liddell et al., 2005; Williams et al., 2006), although it has also been suggested that this may be due to the stimuli being inadequately masked (Pessoa et al., 2006).

The excellent temporal resolution of ERPs had provided evidence informing the temporal correlates of the neural circuits engaged by nonconscious and conscious perception of emotion. Specifically, that the first 200 milliseconds of processing is sufficient time for top-down unconscious processing (Molholm et al., 2002), whereas conscious perception is distinguished by sustained and prominent activity beyond 300 milliseconds post-stimulus (Bernat et al., 2001; Kiefer & Spitzer, 2000; LeDoux, 1998; Williams et al., 2004). Several recent ERP studies has produced solid evidence of brain responses to subliminal emotional faces and the early processing of successfully masked facial expressions (typically fearful and neutral expressions) while the absence of any residual awareness has been monitored. Liddell et al. (2004) showed initial evidence that the earliest difference between fearful and neutral faces was reflected by the N2 component. However, more recent studies have observed even earlier differences generally within 140–180 ms time window, over anterior electrodes (Kiss & Eimer, 2008), and over temporal electrodes (Pegna et al., 2008), particularly on the N170 component. While the majority of studies using subliminal or masked procedures have investigated perception of fearful facial expressions, disgust and happy expressions have been shown to be processed without conscious awareness (Smith, 2012), and subliminal processing of emotional stimuli has also been demonstrated even when stimuli are not attended to (Pegna, Darque, Berrut, & Khateb, 2011). Taken together, such findings demonstrate early unconscious processing of emotional stimuli, and are consistent with the proposed rapid colliculo-pulvino-amygdalar pathway (LeDoux, 1998; 2012), which may allow emotional stimuli to be processed prior to the onset of conscious awareness.

There is thus an increasing evidence base suggesting that subliminal or masked research designs are superior at elucidating condition effects in early ERP components. In addition, even a minute degree of conscious processing may dampen these automatic unconscious processes given that it is possible for some level of conscious detection of stimulus features to occur prior to emotion discrimination (Bernat et al., 2001; Williams, et al., 2004). The failure in the current thesis to find consistent evidence supporting either the motivational model or the negativity bias model and the lack of findings in early ERP components may therefore be reflective of the research paradigms we employed. Specifically, use of a subliminal or masked task may have been better at elucidating early unconscious processing reflected by early ERP components as conscious task processing in the current series of studies may have interfered with our measurement of unconscious processesing of the emotional stimuli.

Relatedly, a limitation of ERPs is that they may not be sensitive enough to detecting differences, including sex differences, in activation of subcortical structures, networks, or driven processes given their poor spatial resolution as compared to neuroimaging measures where permit the functional role of subcortical structures relevant to emotion processing and emotion regulation to be explored.

10.3. Sex Differences in Emotion Processing

10.3.1. Behavioural Data

The aim of Study 1 was to explore sex differences in behavioural and cortical reactivity to pleasant, unpleasant, and neutral stimuli in order to investigate whether women exhibit greater processing of emotional stimuli in general, consistent with the motivational model, or of unpleasant stimuli specifically, in accordance with the negativity bias hypothesis. If evidence of the motivational model in women was to be observed, we predicted that women would have higher ERP amplitudes and similarly rate both the pleasant and unpleasant stimuli as being significantly more pleasant and unpleasant respectively and more arousing relative to men. Conversely, we anticipated that women would rate the unpleasant stimuli as being more unpleasant and more arousing, and display larger ERP amplitudes, than men if support for the negativity bias was found, with no differences in valence or arousal ratings (or cortical activity) for the pleasant or neutral stimuli. While no sex differences in valence or arousal ratings for pleasant or neutral stimuli were shown for either sex, women were found to rate the unpleasant stimuli as being significantly more arousing than men, consistent with the predictions of the negativity bias.

The stimuli ratings data obtained in Study 1 demonstrated a negativity bias in women. This finding is consistent with previous emotion processing literature which has used static image and film clip stimuli to find sex differences in behavioural responses to emotional stimuli. Specifically, women, when compared to men, have been shown to have greater sensitivity towards emotional stimuli, to rate unpleasant stimuli as being more unpleasant and more arousing, to report experiencing greater levels of emotion, and to be faster and more accurate in identifying unpleasant emotions (e.g., Armbruster et al., 2014; Bianchin & Angrilli, 2012; Bradley et al., 2001; Collignon et al., 2010; Hoffmann et al., 2010; Kret & De Gelder, 2012; Lang & Bradley, 2010; Montagne et al., 2005; Quevedo et al., 2010; Ros & Latorre, 2010; Sass et al., 2010; Sharp et al., 2006; Syrjanen & Wiens, 2013; Whittle et al., 2011). Emotion regulation strategy was investigated in Study 3. However, investigating sex differences in emotion regulation ability rather than in regulation strategy, Kong et al. (2014) showed that men score higher in emotion regulation ability than women, a finding which supports previous research (e.g., Kong, Zhao, & You, 2012). This outcome may suggest that men activate emotion regulation via cognitive control mechanisms and women by reducing emotion reaction mechanisms. Future research should further examine emotion regulation ability as this could have significance for understanding sex differences as emotion regulation may proceed via different mechanisms for men and women.

10.3.2. Electrophysiological Data

In Study 1 we investigated whether women display increased processing of unpleasant stimuli specifically (negativity bias hypothesis) or of emotional stimuli in general (motivational model). While the behavioural data in Study 1 demonstrated a negativity bias in women, the obtained ERP data did not reveal evidence for either a negativity bias or enhanced general emotional processing (motivational model) in women. Women displayed an increase in mid-latency cortical processing (N2), thought to reflect early conscious attention allocation (Anderson & Stanford, 2012), to both unpleasant and neutral stimuli, whereas men displayed an increased N2 amplitude to neutral stimuli. These findings do not confirm previous research which has revealed evidence for a female negativity bias in early ERP components (Gardener et al., 2013; Li et al., 2008; Lithari et al., 2010) as reflected by enhanced N1 and N2 amplitudes to unpleasant relative to pleasant and neutral stimuli. Hence, the evidence from Study 1 did not provide conclusive support for either the negativity bias or motivational model, and was inconsistent to previous research, possibly as a result of various methodological issues associated with the study design.

One potential methodological factor in this failure to replicate a negativity bias in women in the use of the dual-task in Study 1. Many of the previous studies reporting evidence of female negativity biases have used passive viewing tasks (e.g., Gardener et al., 2013; Han et al., 2009; Lithari et al., 2010; Luo et al., 2009). Study 1 contained an emotion categorisation task presented in a dual-task condition where visual oddball stimuli were concurrently presented with emotional images. It is possible that overlaying an attentional task when investigating emotion processing, may enhance attentional processing of all stimuli presented, which may lead to reduced differential processing of emotional stimuli (Pessoa, Kastner, & Ungerleider, 2002; Vuilleumier & Driver, 2007). As prior research has shown emotion processing (and regulation) to drain available resources for subsequent cognitive processing (e.g., Inzlicht & Gutsell, 2007; Schmeichel, 2007), it is likely that cognitive (i.e., attentional) processing similarly depletes resources available for emotion processing. Thus, this dual-task design may have reduced the availability of cortical resources for processing the emotional stimuli (Pratt et al., 2011). Consequently, as the dual-task design may have confounded cortical responses to the emotional stimuli by blunting attentional effects observed in early P1 and N1 components, the remaining studies informing this thesis utilised ‘pure’ tasks (passive viewing) which allow the un-confounded cortical processing of emotional stimuli to be assessed.

A second potential confound in Study 1 was that a large proportion (75%) of the pleasant stimuli depicted scenes of sexual erotica. This may have been a confounding factor as a bias for erotic visual material has been previously reported when erotic stimuli are presented among other pleasant stimuli, with men typically found to be more reactive to erotica than women (Rupp & Wallen, 2008). Further, the inclusion of erotica stimuli may have reduced potential negativity bias effects that are more apparent in studies which have omitted erotic stimuli from their experimental tasks (e.g., Lithari et al., 2010). As outlined in Chapter 7, women in Study 1 exhibited greater responsiveness to the pleasant stimuli than men, a finding which is divergent to the majority of previous research which typically reports greater processing of erotica in men relative to women (e.g., Bianchin & Angrilli, 2012; Bradley & Lang, 2007; Bradley et al., 2001a; Chivers et al., 2010; Hamann, Herman, Nolan, & Wallen, 2004; Lang et al., 1997; Proverbio, Adorni, Zani, & Trestiana., 2009; Rozenkrants & Polich, 2008b; Sabatinelli et al., 2004; Sass et al., 2010; Wrase et al., 2003). Further, our finding differs from previous research which has shown that women relative to men to find erotica stimuli to be disgusting rather than positive (Curtis, Aunger, & Rabie, 2004; Fleischman, 2014; Grauvigl et al., 2014; Haidt, McCauley, & Rozin, 1994; Tybur, Bryan, Lieberman, Caldwell Hooper, & Merriman, 2011).

Furthermore, when considering this unexpected finding, research has demonstrated that women during their high estradiol (i.e., ovulatory) menstrual cycle phase have been found to have heightened sensitivity to erotic stimuli (Krug et al., 2000). As Study 1 contained erotic stimuli and the impact of menstrual phase was not controlled, it is important for potentially confounding effects of menstrual phase to be considered as it is possible that our female sample contained a majority of women in the high estradiol phase of their menstrual cycle. To avoid confounding higher order emotional processing with sexual arousal or the effects of menstrual phase, the subsequent studies did not contain sexually erotic stimuli. This enabled us to explicitly control for the valance and arousal of stimuli, and assess the modulation of emotion processing as a result of menstrual phase.

Hence, another key uncontrolled variable which may explain inconsistency of Study 1 from previous literature is the impact of menstrual phase. As discussed previously, recognition of the influence of sex hormones on emotional processing is growing (see Toffoletto et al., 2014). At the level of brain responses, neuroimaging studies examining emotion processing have observed substantial menstrual cycle modulation of the limbic network (e.g., amygdala). More specifically, research investigating female cortical reactivity to emotional stimuli during different phases of the menstrual cycle has shown decreased limbic and frontal region activity during the late follicular phase relative to the early follicular phase (Goldstein et al., 2005) and increased amygdala and hippocampal activity during the midluteal phase compared to the early follicular phase (Andreano & Cahill, 2010; Bayer et al., 2014; Gingnell et al., 2012). Further, van Wingen et al. (2008) reported that an exogenous dose of progesterone corresponding to natural levels during the midluteal phase results in increased amygdala and hippocampus activation. Thus, a core limitation of Study 1 (and of many ERP emotion studies) is that we did not control for the powerful influence of menstrual phase on the cortical processing of emotion, with the observed results potentially reflecting this omission. Following from this evidence that the midluteal phase is associated with greater limbic activity to emotional stimuli, Study 2 aimed to extend Study 1 by investigating whether the midluteal menstrual phase is associated with a negativity bias to unpleasant stimuli or with greater processing of emotional stimuli in general.

10.4. Impact of Menstrual Phase during Emotion Processing

10.4.1. Behavioural Data

Study 2 extended Study 1 by examining the impact of menstrual phase on behavioural and cortical responses to neutral, and low- and high- arousing pleasant, unpleasant stimuli. Following the results of Study 1, we predicted that if midluteal women displayed a negativity bias, they would demonstrate greater valence and arousal ratings and increased ERP amplitudes specifically to unpleasant stimuli, whereas if they displayed greater stimuli ratings and ERP amplitudes to unpleasant and pleasant relative to neutral, this would support the motivational model.

In line with the negativity bias hypothesis, both women in their early follicular and midluteal phases of their menstrual cycle rated the unpleasant stimuli as being more unpleasant than men, with early follicular and midluteal women also rating the low-arousing stimuli as being more arousing than men. This finding reflected a sex difference that was not modulated by menstrual phase. Such a sex difference is in accordance with previously discussed research examining differences in emotion processing between women and women which has reported a negativity bias in women (e.g., Armbruster et al., 2014; Bianchin & Angrilli, 2012; Collignon et al., 2010; Hoffmann et al., 2010; Kret & De Gelder, 2012; Lang & Bradley, 2010; Montagne et al., 2005; Quevedo et al., 2010; Ros & Latorre, 2010; Sass et al., 2010; Sharp et al., 2006; Syrjanen & Wiens, 2013; Whittle et al., 2011).

10.4.2. Electrophysiological Data

While no evidence of P1 or N1 modulation was found in Study 1 where the impact of menstrual phase was not controlled, novel evidence for menstrual phase modulation of early visual processing was revealed in Study 2. The behavioural data in Study 2 demonstrated a negativity bias in women. However, against predictions ERP data observed in Study 2 did not show clear evidence of the predicted negativity bias or motivational model effects. Rather than display heightened sensitivity to the unpleasant stimuli specifically or to emotional stimuli in general, women in the midluteal menstrual phase were found to exhibit significantly greater early P1 (at occipital region) and N1 (at frontal region) reactivity to *all* visual stimuli (emotional and neutral) as compared to early follicular women, and particularly to men. Further, we found the P3 and LPP component amplitudes to be larger to the highly-arousing unpleasant stimuli relative to all other stimuli conditions which provided some support for the negativity bias during late cortical processing. However, no differences in late cortical activity as a result of sex or menstrual phase were observed. The P3 and LPP magnitude increases were observed across both women and men, and across both the early follicular and midluteal menstrual phases, which does not provide evidence of a negativity bias in women, or in midluteal women specifically.

The findings in Study 2 did not demonstrate prioritised processing of emotional stimuli in general (in line with the motivational model) or of unpleasant stimuli specifically (consistent with the negativity bias hypothesis). Alternatively, midluteal women were found to display generally enhanced preconscious processing of visual stimuli relative to early follicular women, and markedly to men, with no sex or menstrual phase differences revealed during late conscious processing.

The finding of enhanced P1 amplitude indicates that midluteal women display greater early preconscious visual processing of visual emotional stimuli than early follicular women and men. This explanation is supported by prior research which has linked early preconscious visual attention processes to the P1 component when activated in the occipital cortex (Avitabile et al, 2007;

Luck et al., 2000). Furthermore, as was discussed in detail in Chapter 8, the P1 interpretation is in accordance with previous behavioural data which has demonstrated a relationship beween high levels of progeseterone (i.e., midluteal menstrual phase) and enhanced visual processes including greater visual perception, attention, and memory (Phillips & Sherwin, 1992; Solis-Ortiz & Corsi-Cabrera, 2008; Wijayanto et al., 2009). Our P1 finding also supports more recent research by Wassell et al. (2015a, 2015b) which found that progesterone level predicted increased visual reactivity, improved visual memory, and greater imagery capacity in midluteal women as compared to men and to women in the early follicular phase of their menstrual cycle.

In addition to ERP evidence, a relationship between the occipital region (i.e., visual processing region) and the amygdala (i.e., emotion processing region) has been established by prior neuroimaging literature, as amygdala reafferants have been implicated in the processing of stimuli in the visual cortex (de Kloet et al., 2005). Neuroimaging research has reported increased amygdala activation during the processing of visual stimuli (relative to other sensory stimuli; Boubela et al., 2015; Phan et al., 2002), emotional stimuli (Costafreda et al., 2008; Stevens & Hammond, 2012), and salient stimuli (Davis & Whalen, 2001; Edminston et al., 2013; Liberzon et al., 2003; Mendes et al., 2007), including neutral stimuli if perceived as salient and task relevant (Cooney et al., 2009; Davis & Whalen; Fusar-Poli et al., 2009; Schwartz et al., 2003). As was noted in Chapter 8, this body of neuroimaging evidence demonstrates the importance of the amygdala during early processing of visual stimuli, with amygdala activity shown to be increased in midluteal women (Andreano & Cahill, 2010; Bayer et al., 2014). Hence, the current P1 effect observed for midluteal women extends existing behavioural and neuroimaging data by providing electrophysiological evidence that midluteal women display greater preconscious processing of visual stimuli in general, relative to early follicular woman, and especially to men.

Similar to the P1 findings, midluteal women were found to have significantly greater N1 amplitudes than men (Study 2). Since a frontally maximal N1 is indicative of early initial preconscious allocation of attention (Dong et al., 2011; Hajcak et al., 2010; Olofsson et al., 2008), the obtained N1 findings suggest that women, particularly midluteal women, display increased automatic activity in frontal attention networks as compared to men. This finding is consistent with previous research demonstrating increased N1 amplitudes in women (e.g., Gardener et al., 2013; Li et al., 2008; Lithari et al., 2010). Of importance is that the majority of prior studies have reported enhanced N1 in response to unpleasant emotional stimuli specifically (reflecting a female negativity bias), whereas in Study 2 we observed the P1/N1 effects across emotional (pleasant and unpleasant) and neutral stimuli conditions. Controlling for menstrual phase may explain why we did not find evidence of the anticipated negativity bias (or of greater responsivity to emotional stimuli in general) in women in Study 2. Of interest, we conducted analyses collapsed across early follicular and midluteal menstrual phase to allow us to directly examine sex differences. However, following this analysis we still did not find evidence of either a negativity bias or greater emotionality in women during early cortical processing (see above and Appendix G).

An alternative explanation for why we did not observe a female negativity bias or evidence for the motivational model may be that women, especially women in the midluteal menstrual phase, may have a reduced positivity bias. A positivity bias has been reported in men and refers to when processing of pleasant stimuli elicits comparable or even more enhanced responses relative to unpleasant stimuli (e.g., Brown et al., 2012). Additionally a positivity bias between pleasant and neutral stimuli has also been demonstrated by a recent meta-analysis which reported a modest attentional bias for pleasant compared with neutral stimuli in both early and late processing (Pool et al., 2016). However, while an interesting possibility, we found no evidence of women having a decreased positivity bias in the current series of studies. Nevertheless, this notion could be further explored in future research as an alternative reason for women having increased anxiety prevelance, whereby women may have a reduced positivity bias which leads them to experience anxiety at greater rates than men.

The small number of ERP studies which have considered the impact of menstrual phase have, in fact, found inconsistent results. Wu et al. (2014) demonstrated N2 amplitude to be higher to both moderately and highly unpleasant stimuli relative to neutral stimuli in the mid-late luteal phase, providing evidence for a negativity bias in in midluteal women. Relatedly, but not showing evidence of a negativity bias, Zhang et al. (2015) found LPP amplitude to be greatest during the luteal phase compared to the early follicular and late follicular menstrual phases. In contrast however, rather than find support for either the motivational model or negativity bias in women, Zhang et al. (2013) revealed LPP amplitude to be higher to all task stimuli (pleasant, unpleasant, and neutral facial stimuli) during the mid-late luteal phase relative to the early follicular and late follicular phases. Overall, there is a limited literature base to which we can compare the findings of Study 2. However, while the midluteal effect in Study 2 was found in early preconscious processing (P1/N1), our finding of greater cortical reactivity to emotional and neutral stimuli is consistent with Zhang et al. (2013), and indicates a generalised effect of enhanced visual processing in women in the midluteal phase of the menstrual cycle. There is a clear need to future research to explore menstrual phase effects on visual processes to allow replication of the current findings.

10.4.3. Impact of Testosterone during Emotion Processing

Testosterone is an androgen steroid hormone produced in the testes in men and ovaries in women, with men producing significantly higher levels of testosterone than women (Prather, 2016). Testosterone has been implicated in emotion processing with research suggesting that testosterone influences defence behaviours (Taylor et al., 2000) whereby testosterone may decrease fear and aversion to unpleasant and/or threatening stimuli. The aversion-reducing properties of testosterone have been demonstrated using a wide range of behavioural research paradigms in both animals (e.g., Aikey et al. 2002; Frye & Seliga 2001) and in humans (e.g., van Honk et al., 2001; 2005). In healthy participants, a single administration of testosterone has been shown to decrease the recognition of angry and fearful facial expressions (van Honk et al. 2001; 2005). Positive relationships in both women and men have been found between testosterone levels and vigilance to angry faces (Van Honk et al., 1999). Similarly, Wirth and Schultheiss (2007) demonstrated that higher testosterone levels predicted better learning on sequences paired with sub-threshold (i.e., presented too fast for conscious awareness) angry faces.

At the level of neural brain responses, Stanton et al. (2009) found that endogenous testosterone levels were negatively correlated with amygdala BOLD activity and positively correlated with ventromedial prefrontal cortex BOLD activity during the processing of angry faces. Such a result further supports the negative relationship between amygdala and ventromedial prefrontal activity. It has been suggested that this may contribute to sex differences in the vulnerability to psychiatric disorders (Kessler et al., 2005; Kret & De Gelder, 2012). However, other studies have failed to find significant correlations between testosterone levels and brain activation (e.g., Ji et al., 2015). The recent review article by van Wingen, Ossewaarde, Backstrom, Hermans, and Fernandez (2011) concluded that progesterone enhances connectivity between the amygdala and the medial prefrontal cortex whereas testosterone decreases connectivity between the amygdala and the orbitofrontal cortex, thus potentially promoting emotion regulation.

Very few ERP studies has been conducted examining the impact of testosterone on emotion processing. Champagne, Mendrek, Germain, Hot, and Lavoie (2014) examined electrocortical responses to emotional images and testosterone levels with ERPs and showed that testosterone level was negatively correlated with P3 amplitude to pleasant stimuli but not to unpleasant stimuli. In contrast, Chen et al. (2015) demonstrated that administration of a single dose of testosterone increased P3 amplitude to pleasant and unpleasant stimuli using an auditory oddball paradigm.

Altogether, these findings generally suggest that testosterone modulates behavioural and neural activity during processing of emotional stimuli in healthy people, particularly men, although the exact mechanism is unclear and some contrasting findings have been reported. Overall however, studies investigating the effect of testosterone on emotion processing indicate that testosterone reduces aversion to unpleasant stimuli and increases emotion regulation capacity.

Unfortunately testosterone data was not available for the current thesis due to the expense of additional assays. However, as testosterone has been shown to influence emotion processing and the regulation of emotional responses and affective states, it is reasonable to suggest that testosterone may therefore have mediated some of the sex and menstrual phase differences observed in the current thesis. Specifically, testosterone may have provided protection against negativity biases during the processing of emotional stimuli (Studies 1 and 2) and enhanced men's ability to regulate their emotional responses relative to women (particularly midluteal women) in Study 3. Given the excellent temporal resolution of ERPs and the lack of ERP and testosterone research to date, the use of ERPs to examine testosterone effects on emotion processing and emotion regulation is an area which warrants future research.

10.5. Theoretical Implications

10.5.1. Evidence for the Motivational Model and Negativity Bias Hypothesis

In summary, whilst the first two studies in the current program of research aimed to test if women displayed a negativity bias or general enhancement of emotional processesing (consistent with the motivational model), the ERP findings did not support either model clearly. Several factors may be influencing these findings and leading to divergences from previous literature; as discussed above, this may involve the use of a dual-task paradigm, sexually explicit stimuli, and the failure to control for menstrual phase in Study 1. However, Study 2 employed a passive viewing task, balanced stimuli valence and arousal dimensions, and controlled for menstrual phase, and also did not reveal evidence of a negatitivity bias in women, or of generalised enhancement of emotional processing.

Rather, a novel and unexpected finding was observed as women in the midluteal menstrual phase were shown to have generally enhanced early visual reactivity instead of a specific processing bias towards emotional stimuli in general or unpleasant/threatening stimuli specifically. As previously outlined, this finding is convergent with research revealing a relationship between high progesterone levels and enhanced visual attention, visual perceptual processing, visual imagery, and visual memory (Avitabile et al., 2007; Phillips & Sherwin, 1992; Solis-Ortiz & Corsi-Cabrera, 2008; Wassell et al., 2015a, 2015b; Wijayanto et al., 2009). Moreover, the current finding of generally enhanced early visual processing in midluteal women is reflective of the association between visual processing regions and the amygdala reafferents during the processing of stimuli in the visual cortex (de Kloet et al., 2005). The impact of menstrual phase on visual and emotion processing thus warrants futher investigation.

It was notable that the behavioural data involving self-report ratings of valence and arousal did support a negativity bias in women (which was not strongly modulated by menstrual phase). It is possible that self-report valence and arousal ratings may be more susceptible to sociocultural factors, such as socialisation and gender roles, than cortical ERP data which may be more influenced by biological factors. Such a difference may account for greater self-reporting of a negativity bias in women than in men.

The finding of enhanced visual reactivity which generalised across all stimuli (irrespective of valence or arousal) in midluteal women (reflecting greater sensory arousal and initial attention) is novel, and may have potentially interesting implications for later emotional processes such as emotion regulation. As outlined previously, both the process model of emotion regulation and the process-specific timing hypothesis models propose that heightened initial reactivity to emotional stimuli depletes processing resources leading to impairment in later emotion regulation processing (Gross & Thompson, 2007; Sheppes & Gross, 2011). The process-specific timing hypothesis expands this ‘timing’ focus to suggest emotion regulation strategies applied during late emotion regulation processing (suppression) are less effective than regulation strategies applied during early emotion regulation processing (reappraisal) as the strength and intensity of the emotional response to be regulated has become stronger and more intense (Sheppes & Gross).

10.5.2. Emotion Regulation

To test the predictions of the process-specific timing hypothesis, Study 3 was conducted to investigate early emotional reactivity (P1, N1) and later emotion regulation (P3, LPP) controlling for menstrual phase. We expected that women in the midluteal menstrual cycle phase would demonstrate enhanced P1 and N1 amplitudes to unpleasant stimuli, and greater difficulty in decreasing their processing of the unpleasant stimuli. This would be reflected by increased distress and effort ratings, and by smaller P3 and LPP amplitude reductions, as compared to men and to women in the early follicular menstrual cycle phase. Comparable to Study 2, and in line with our hypotheses, women relative to men exhibited greater preconscious processing of the visual stimuli, as reflected by larger P1 and N1 amplitudes at occipital and frontal sites respectively, regardless of regulation instruction. Notably, as was the case in Study 2, this early female processing bias was impacted by menstrual phase as midluteal women showed significantly greater P1 and N1 activation than men.

The most noteable finding of Study 3 was that women, particularly midluteal women, exhibited larger N2 amplitude following suppression instruction than men. This was an unexpected finding as we anticipated deficits in late (P3/LPP) emotion regulation processes following suppression. The N2 component indexes early selective attention within visual processing paradigms, and thus reflects conscious attention being directed to emotional stimuli in emotion processing paradigms (Anderson & Stanford, 2012; Balconi & Lucchiari, 2007, Patel & Azzam, 2005; Schupp et al., 2006).

The N2 result supports the argument that women, especially women in the midluteal phase of their menstrual cycle, are less able than men to suppress cortical processing of unpleasant stimuli. The obtained behavioural data strengthened the interpretation of the N2 finding and showed a sex effect in the level of emotional distress experienced during suppression. Specifically, both early follicular and midluteal women reported more distress compared to men. Additionally, a menstrual phase effect in the level of effort required when suppressing emotion response to the stimuli was found, with midluteal women exerting greater effort than early follicular women, and significantly greater effort than did men, a result which directly compliments the N2 finding. The increased effort required by midluteal women and the effect of this requirement on conscious processing (reflected by the N2 component) accords with previous ERP research which has demonstrated N2 amplitude to be higher when greater levels of conscious effort are required for task completion (e.g., Go/Nogo tasks, Benikos et al., 2013). Further, our N2 finding indicates that midluteal women required more effort and cortical processing than men as they endeavoured to suppress their emotional responses, and this is consistent with neuroimaging data which has demonstrated that as compared to women, men have a more proficient ability to suppress emotional stimuli (McRae et al., 2008).

The finding of enhanced early cortical processing in women relative to men is consistent with prior literature which has shown larger P1 and N1 amplitudes to unpleasant stimuli in women compared to men representing a negativity bias in women (e.g., Gardener et al., 2013; Groen et al., 2013; Han et al., 2008b; Li et al., 2008; Lithari et al., 2010; Luo et al., 2014; Yuan et al., 2009). However, despite this finding, it cannot be concluded that there is a negativity bias in midluteal women as no neutral baseline stimuli were presented in Study 3. Rather, given the findings of Study 2, this greater P1/N1 reactivity is likely reflecting generally enhanced visual processing and greater frontal network activation in midluteal women relative to men. In line with the process-specific timing hypothesis which proposes that high levels of emotional reactivity lead to poorer emotion regulation ability (Sheppes & Gross, 2011), it it likely that generally enhanced visual reactivity (to all stimuli regardless of valence or arousal) may similarly impair later emotion regulation processes in the same way as heightened emotional reactivity, particularly for later suppression relative to earlier reappraisal regulation strategy. Hence, rather than reflecting a negativity bias or an enhanced cortical response to emotional stimuli, the convergent behavioural ratings and N2 amplitude findings suggest that the enhanced visual reactivity exhibited by midluteal women reduced the conscious processing resources available during suppression. It is argued that this subsequently resulted in an impaired capacity to suppress negative emotional processing in midluteal women.

We considered why this effect was specific to suppression and not seen in reappraisal as well. According to the process-model of emotion regulation, reappraisal is an antecedent strategy which influences emotional responses prior to the formation of emotion response tendencies whereas suppression is a response-focussed strategies that is used after exposure to an emotion inducing stimulus which alters the expression of an emotional response following the formation of response tendencies (Gross & Thompson, 2007). In line with the generic timing hypothesis proposed in the process-model of emotion regulation, antecedent-focused strategies, such as reappraisal, are more effective than response-focused strategies, such as suppression, as they modify emotion early in the emotion-generation process while the strength of an emotional response is still increasing. Further, suppression involves the use of behavioural strategies for the reduction of emotionally expressive behaviour, such as inhibiting or concealing emotions as they arise, which results in modulation of one's emotional response rather than of their emotional experience (Gross & John, 2003; Hajcak & Nieuwenhuis, 2006). We therefore suggest that deficits in emotion regulation were not observed in reappraisal as it is a more adaptive strategy than suppression which only intervenes late in the emotion-generative process once the strength of emotions have intensified.

We found evidence of successful emotion regulation, reflected by decreased P3 amplitude during suppression, indicating that suppression was an effective strategy to decrease responsiveness to the unpleasant stimuli regardless of group. This finding is consistent with Moser et al. (2006) who revealed significantly decreased LPP amplitude during suppression of emotional response to unpleasant stimuli. However, while we found menstrual phase modulation during early preconscious and early conscious processing, no sex or menstrual phase effects during late (P3, LPP) emotional regulation processing were demonstrated.

ERP emotion regulation studies, which involved participants passively viewing or reappraising unpleasant images, have reliably shown LPP amplitude elicited by unpleasant stimuli to be reduced when reappraisal is employed to down-regulate emotional responses (e.g., Devenley & Pizzaigalli, 2008; Hajcak & Nieuwenhuis, 2006; Hajcak et al., 2010; Moser et al., 2009, 2010). Conversely, while consistent with Gardener et al. (2013), we observed no reduction in distress or effort self-reports, or in early conscious processing (N2) or late conscious processing (P3, LPP) amplitudes during reappraisal of emotional response. This is surprising given we replicated the procedures, including the same standardised regulation instructions, as Moser et al. (2010). One possibility is that the impact of emotional valence may have overridden the impact of emotion regulation instruction. More specifically, the P3 and LPP components are seen to reflect conscious emotion processing and have been shown to influence emotion regulation through the prioritisation of attentional resource allocation to emotional relative to neutral stimuli (Hajcak et al.). This valence effect may therefore have superseded the effect of reappraisal emotion regulation strategy on the reduction of emotional response. Further, the divergence between the current study and previous literature may be the result of methodological differences given that previous research has overlaid an emotion regulation task upon a cognitive processing task (e.g., Moser et al., 2010), examined LPP at later time windows than the current study (e.g., 1000-1800ms, Moser et al., 2010), involved an instruction to increase emotional responses to unpleasant stimuli (e.g., Moser et al., 2009), or failed to examine menstrual phase (e.g., Hajcak & Nieuwenhuis).

Our overall pattern of findings of increased early reactivity (reflected by P1 and N1 amplitudes) during both reappraisal and suppression, and reduced emotion regulation (reflected by N2 amplitude) during suppression were in line with predictions of Sheppes and Gross (2011). However, as outlined in Chapter 9, when directly testing this model by examining correlations between early ERP components indexing emotional reactivity (P1, N1) and later ERP components indexing emotion regulation (P3, LPP) we only found two correlations between early reactivity and later emotion regulation indices. While the direction of these correlations was consistent with this prediction, they were only found in men and not women as would be expected. However, these correlations should be cautiously considered given the substantial inter-individual variability in ERPs and the need for the novel N2 finding to be reproduced in future studies.

We did not find significant correlations between early reactivity (P1, N1) and later emotion regulation (P3, LPP) for midluteal women.

Subsequently, to further explore the finding of enhanced early reactivity and reduced suppression capacity (reflected by N2 amplitude) in midluteal women we conducted Pearson product-moment correlations between P1, N1, and N2 separately for early follicular women, midluteal women, and men (Appendix N). Following Bonferroni adjustment we found three correlations between early reactivity (N1) and early conscious processing (N2). No significant correlations were revealed for early follicular women. However, a significant positive correlation between N1 and N2 during suppression was revealed for midluteal women indicating that increased N1 amplitude is associated with greater N2 amplitude following suppression instruction. Interestingly, we also found significant, positive correlations for men between N1 and N2 during reappraisal and suppression which similarly demonstrated that increased early reactivity was related to reduced suppression capacity in men, although this pattern was not observed in the ERP data. While the correlations were similar in midluteal women and men rather than being specific to midluteal women, we nevertheless suggest that the correlation between N1 and N2 for midluteal women strengthens the ERP evidence that midluteal women exhibit enhanced early emotional reactivity and reduced capacity to suppress their emotional responses as compared to men.

While neuroimaging studies have reported on the effects of menstrual phase on emotion processing (e.g., Andreano & Cahill, 2010; van Wingen et al., 2008), very few ERP studies examining menstrual phase modulation of visual emotion processing have been conducted to date. Indeed, to our knowledge, no emotion regulation studies controlling for the impact of menstrual phase have been previously published. Subsequently, when questioning why emotion regulation effects were not observed in Study 3, and thus of key importance to the current thesis, is that earlier ERP emotion regulation studies have failed to control for menstrual phase (e.g., Gardener et al., 2013; Moser et al., 2006, 2009, 2010). Thus, an area yet to be fully explored is the impact of menstrual phase on emotion regulation given that menstrual phase has been shown to modulate the limbic network, with such modulation potentially impacting emotion regulation processes (Andreano & Cahill; Etkin, 2009; Farb et al., 2012; Goldstein et al., 2005). It is also noteworthy that the majority of previous neuroimaging studies examining sex differences in emotion regulation are inconsistent and do not provide a conclusive understanding of the differences in emotional reactivity or emotion regulation capacity between women and men (e.g., Domes et al., 2010; McRae et al., 2008).

In summary, Study 3 (and Study 2) clearly demonstrates novel evidence of early reactivity and preconscious processing of visual stimuli in the midluteal phase. In line with existing emotion regulation literature (Gross & Thompson, 2007; Sheppes & Gross, 2011), this early reactivity occurs in conjunction with a lowered capacity to use suppression emotion regulation strategy to down-regulate emotional responses to unpleasant stimuli in women, with this reduced capacity markedly stronger in midluteal women than men. Study 3 has provided the first evidence of sex differences in emotion regulation controlling for menstrual phase. As a result we are unable to directly compare Study 3 to an existing emotion regulation and menstrual phase literature base. Consequently, it is nessesary for future emotional neuroscience research to consider sex and menstrual phase differences in the relationship between early emotional reactivity, or of generally enhanced reactivity to visual stimuli, and the subsequent effectiveness of later emotion regulation strategies in order to replicate and strengthen the findings observed in the current thesis.

10.6. Methodological Issues

10.6.1. Nature of Stimuli

Earlier emotion processing ERP studies reporting support for a female negativity bias often omitted a neutral and/or pleasant stimuli category from their experimental tasks (e.g., Gardener et al., 2013; Smith et al. 2003). This is problematic as there is then no baseline (i.e., neutral) reference point with which to compare responsiveness to emotional (unpleasant and/or pleasant) stimuli. Therefore it is difficult to identify if women displayed generalised reactivity to all visual stimuli, or whether their reactivity is restricted to emotional stimuli per se. To overcome this limitation, neutral and pleasant stimuli conditions were included in Studies 1 and 2. Rather than find a specific processing bias towards emotional stimuli in general or unpleasant stimuli specifically, when we made this methodological change we found novel evidence of a generalised enhancement in early visual processing in midluteal women which accords with recent behavioural literature (e.g., Avitabile et al., 2007; Solis-Ortiz & Corsi-Cabrera, 2008; Wassell et al., 2015a, 2015b; Wijayanto et al., 2009).

As noted previously, the valence and arousal dimensions of stimuli in Study 1 were not fully controlled as we initially selected a stimuli set that displayed a wide variety of semantic contents. Hence a key methodological issue in Study 1 was that the majority of pleasant stimuli in Study 1 were of a sexually erotic nature which may have confounded our findings, especially when not controlling for menstrual phase (Krug et al., 2000). This unbalanced valence/arousal experimental task design deviated from prior emotion processing studies which have commonly used an orthogonal valence (pleasant, unpleasant) by arousal (low, high) task design (e.g., Feng et al., 2012b, 2014; Lithari et al. 2010; Rozenkrants & Polich, 2008). Despite matching on valence and arousal, these previous studies reported divergent findings regarding the impact of valence and arousal on emotion processing as some studies report independent effects of valence and arousal (e.g., Citron, Weekes, & Ferstl, 2013; Citron, Abugaber, & Herbert, 2016; Lithari et al., 2010; Rozenkrants & Polich, 2008) and others have observed an interaction between valence and arousal factors (e.g., Feng et al., 2012a; Recio, Conrad, Hansen, & Jacobs, 2014).

Cacioppo and Bernston (1994) suggest that aversive system activation is stronger than appetitive system activation when stimuli arousal levels are high (negativity bias), while the opposite is observed when arousal levels are low (positive offset). Consistent with this view, as stimuli arousal levels were not adequately controlled in Study 1, arousal may have influenced valence effects causing the pleasant stimuli to modulate (increase or decrease) cortical activity more so than the unpleasant stimuli. It is also possible that using highly arousing pleasant and unpleasant stimuli resulted in generalised increases in arousal, leading to enhanced cortical processing of all stimuli whether emotional (pleasant or unpleasant) or neutral. It is important for emotion processing studies to balance valence and arousal factors as failing to do so may reduce stimuli discriminability and decrease the likelihood of observing a negativity bias or conclusive support for the motivational model.

The IAPS stimuli are commonly used in the emotion literature to explore emotion processing and emotion regulation and contain complex emotional and neutral scenes (Lang et al., 2008). We used the IAPS throughout this program of research as we were interested in reactivity to, and regulation of, emotional scences rather than to alternative stimuli such as facial expressions which are also commonly used to investigate emotion processing (e.g., Choi et al., 2015). However, it was noted in Chapter 2 of the introduction that the motivational model is most relevant to research investigating primary emotional responses, because primary emotions have an intrinsic link with associated approach and withdrawal motivational systems (Damasio, 1995; Deigh, 2014). Despite this, complex stimuli such as IAPS images are also highly suitable to be used as stimuli when assessing support for the motivational model as they also elicit activation of, and permit investigation of, approach and withdrawal systems (e.g., Li et al., 2008: Lithari et al., 2010). It would however be interesting for future research to replicate the current findings using plain stimuli, as it may be that simple face stimuli for example may be a better, or more direct method of assessing support for the motivational model of emotion processing than complex IAPS images.

Given that prior research has demonstrated that emotional responses to neutral stimuli cannot be regulated (e.g., Moser et al., 2010), the decision to omit a neutral baseline condition in the Study 3 emotion regulation task was justified. Further, while many emotion regulation studies have included a pleasant stimuli category (e.g., Krompinger, Moser, & Simons, 2008; Mak et al., 2009), Study 3 did not contain a pleasant stimuli category as we were interested in regulation of unpleasant stimuli and of negative emotions given their relevance to emotion processing deficits in anxiety disorders.

Overall, the studies in this thesis underscore the need for future research to explicitly balance the valence and arousal dimensions of stimuli and to include a neutral stimuli condition to provide a baseline reference point to aid interpretation of emotional findings. In addition, future studies should exclude erotica stimuli from within pleasant stimuli categories in order to prevent sexual arousal or disgust reactions confounding with the cortical processing of emotion.

10.6.2. Task Designs

10.6.2.1. Passive Viewing Task Design

A major review of the past 40 years of emotion ERP research highlights that despite varying tasks being used in different studies including passive viewing tasks, active discrimination tasks, categorisation tasks, and speeded-response tasks, the observed emotional ERP findings are similar across these modalities (Oloffson et al., 2008; Schupp et al., 2006). The passive viewing task paradigm has been a commonly used task in both early and more recent ERP emotion studies (e.g., de Rover et al., 2012; Ferrari, Bradley, Codispoti, Karlsson, & Lang, 2013; Leite et al., 2013; Lithari et al., 2010; Wheaton et al., 2013). The majority of recent ERP studies that have examined sex differences in response to emotional stimuli have employed passive viewing tasks, and have found consistent evidence of enhanced ERP amplitudes to emotional stimuli (e.g., Gardener et al., 2013; Gasbarri et al., 2006; Groen et al., 2013; Li et al., 2008; Lithari et al.; Proverbio et al., 2009), however these studies have not examined the impact of menstrual phase. We chose to use a passive viewing task in the current study whilst evaluating menstrual phase as an important extension of these prior ERP studies.

Active tasks often require the simultaneous completion of emotion and superimposed cognitive processing. The cognitive effort demanded by active tasks may lead to a reduction of attentional resources and a subsequent decrease in emotional processing resources available to process emotional information. In addition, active tasks often require overt behavioural responses which can produce related motor potentials and artefacts (Zhang et al., 2013). As discussed previously, the findings from Study 1 may have been confounded by the visual oddball selective attention task that was conducted concurrently with the emotion processing task, depleting resources for processing salient negative stimuli and potentially minimising negativity bias effects. Consequently, to avoid potential confounding effects, we used a passive viewing paradigm to examine emotional brain response and to replicate the design of the majority of recent ERP emotion-sex difference studies. Though we did not find clear emotion or sex differences despite controlling for confounding factors in Study 2, specific effects were established based on menstrual phase.

ERP studies of sex differences in emotion processing have reported similar findings regardless of whether the task stimuli were emotionally evocative scenes (Huang & Luo, 2006; Ito et al., 1998; Yuan et al., 2007) or human faces depicting expressions of emotion (Britton, Taylor, Sudheimer, & Liberzon, 2006; Proverbio et al., 2009). For example, studies examining attentional biases to emotional facial stimuli have shown enhanced P1 amplitudes (reflecting preconscious processing) (Pfabigan et al., 2014) and greater N170 (a face-selective ERP component) (Choi, Egashira, Takura, Motoi, Nichimura, & Watanuki, 2015) in women relative to men, however, these studies did not control for the impact of menstrual phase. Emotional face expression stimuli are known to induce facial expression recognition rather than direct emotional reactivity (Proverbio et al., 2009; Wild, Erb, & Bartels, 2001). As we were interested in assessing menstrual phase modulation of emotional reactivity and later emotion regulation, we used emotional (and neutral) scenes instead of facial expressions to elicit emotional reaction instead of emotion recognition (Britton et al., 2006; Herba & Phillips, 2004). For this reason, we examined emotion processing using standardised emotional scene stimuli (International Affective Picture System (IAPS); Lang, Bradley, & Cuthbert, 2008) and did not examine the N170 which is an ERP index of facial processing (Choi et al.).

With respect to the emotional stimuli utilised throughout this program of research, the IAPS (Lang et al., 2008) was the only database of visual emotional stimuli available at the commencement of this program of research which had been sufficiently standardised and normed. However, given the age of the IAPS system, it is possible that different results would have been obtained if more modern stimuli had been used instead of the IAPS images. A comparable but newer database of emotional images is the Nencki Affective Picture System (NAPS; Marchewka, Żurawski, Jednoróg, & Grabowska, 2014) which contains 1, 356 realistic, high-quality photographs organised into five categories (faces, people, animals, landscapes, and objects). Future research may thus use a more modern stimuli database to examine the replicability of the current results.

Whether we would find similar menstrual phase findings to those obtained in Studies 2 and 3 in an active viewing task is an empirical question which can only be addressed by using an active viewing task. Future research could investigate the impact of menstrual phase using an active task which includes a behavioural index of visual processing to aid interpretation of ERP data. Similarly, as it is unknown whether different results would be found if a task containing emotional human faces was used and the face-specific N170 component was measured. As such, it would be interesting for future research to examine the processing of emotional facial expression stimuli while controlling for menstrual phase effects.

As discussed above, we found few early ERP component effects and did not observe consistent findings for either the motivational model or the negativity bias model in the current thesis. It is possible that the experimental tasks we used (which allowed measurement of unconscious and conscious processing) may have impacted the obtained findings as subliminal or masked processing has been argued to be better at clarifying unconscious processing that may be dampened by conscious processing (e.g., Kiss & Eimer, 2008; Pegna, Darque, Berrut, & Khateb, 2011; Smith, 2012; Williams, et al., 2004). Hence, a limitation of the current thesis is that we did not utilise a subliminal or masked research task to examine the impact of sex and menstrual phase effects during automatic unconscious processing reflected in early ERP components. Future research should combine different empirical designs, such as subliminal, passive viewing, and emotion regulation tasks, to further investigate the impact of menstrual phase on unconscious and conscious emotion processing and emotion regulation.

10.6.2.2. Emotion Regulation Task Design

While we found ERP (and behavioural) support for the ‘timing’ prediction of the process-specific timing hypothesis (Sheppes & Gross, 2011), the notion that emotion regulation strategies which are targeted at early stages of emotion regulation (e.g., reappraisal) are more effective than emotion regulation strategies which are focused at later stages of emotion regulation (e.g., suppression) could not be examined in Study 3. However, it is interesting to note that the increased cortical processing during down-regulation instructions in midluteal women was observed during suppression, and not during reappraisal.

The emotion regulation task used in Study 3 was adapted from those of Goldin et al. (2008) and Moser et al. (2010) and enabled reappraisal and suppression regulation strategies to be compared against their own baseline (maintain instruction). This design was proposed by these authors to prevent a contamination of emotion regulation strategies with each other, and with a common baseline (maintain instruction). We closely adapted the task design used by Moser et al. which induced electrophysiological modulation by reappraisal and suppression instructions, as compared with their respective maintain instructions. We thus extended Moser et al. by examining cortical activity during the execution of emotion regulation (reappraisal or suppression) compared with their paired maintain condition while controlling for menstrual phase.

To minimise confounding of reappraisal and suppression strategies and to more directly test the process-specific timing hypothesis (Sheppes & Gross), an optimal task design would involve separate passive viewing (i.e., maintain) and emotion regulation (i.e., reappraisal and suppression) blocks within the same task. This design would then allow direct comparison between the different regulation strategies. Future research should also investigate regulation strategy effectiveness in response to stimuli which induce varying levels of emotional reactivity. This would enable further investigation of the process-specific timing hypothesis while also explicitly investigating the impact of menstrual phase on such processing.

10.6.3. State Effects of Processing

Highly pertinent to the study of sex differences and emotion processing is the effect of sex (estradiol, progesterone) and stress hormones (e.g., catecholamines, glucocorticoids) on the physiology and behaviour of women and men. Previous research indicates that secretion of sex hormones is significantly influenced by stress and glucocorticoids in a sex- and hormone-dependent fashion (Bale & Epperson, 2015; Becker et al., 2006). Additionally, sex hormones themselves can differentially affect sensitivity and responsiveness to stress and can thus result in differential responsiveness to incidental stress in women and men (Bale & Epperson; Becker et al.; Fernández-Guasti, Fiedler, Herrera, & Handa, 2012). Thus, research examining sex differences should consider the possible moderating impacts of stress and stress hormones when conducting emotion processing studies. This question of the interaction of sex and stress hormones was beyond the scope of the current study. Whilst salivary assays were conducted for estradiol and progesterone, unfortunately the estradiol data was artefactual and unable to be included in the analyses, which significantly limited the capacity to explore the impact of sex hormones on the data.

Further potential modulatory factors include previous trauma (especially childhood trauma) and acute stress levels. Emotion processing has been shown to be modulated by early experiences of stress and by acute stressors, and stress has been shown to impact early (e.g., emotional reactivity) and later (e.g., emotion regulation) processes. Negative experiences early in life have been shown to modulate emotion processing throughout one's lifetime by way of influence on stress reactivity (Bale & Epperson, 2015; Loman & Gunnar, 2010) and impact on the development of neural systems associated with complex cognitive and emotion functions (Pechtel & Pizzagalli, 2011).

The effect of childhood adversity on cortical activity elicited by emotional stimuli and by down-regulation instructions was investigated by Pietrek et al. (2012). Healthy controls and depressed and borderline personality disorder participants with low or high levels of childhood stress passively viewed unpleasant and neutral images or down-regulated their emotional responses to the unpleasant stimuli through reappraisal. While healthy, depressed, and borderline participants exhibited enhanced early response to unpleasant relative to neutral images, both clinical groups failed to show reduction in subsequent brain activity following down-regulation instructions, with this emotion regulation deficit markedly evident in those participants who reported high levels of childhood adversity. These results were interpreted by Pietrek et al. as evidence of intact emotional input processing but diminished emotion regulation ability in emotional disorders and of a moderating impact of early life stress of later emotion processing capacity.

Emotional reactivity and emotion regulation difficulties have been implicated in anxiety disorders. Individuals with anxiety disorders have been shown to have facilitated early visual processing of unpleasant images and enhanced P1 for unpleasant compared to neutral stimuli in anxious relative to control participants has been reported (e.g., Holmes et al., 2008; Mueller et al., 2008; Weinberg & Hajcak, 2011). As participants who reported a history or current experience of prolonged stress, trauma, or psychiatric disturbance were excluded from participation, this leads us to question whether different results than those obtained in the current thesis would be observed in participants who were previously or currently under stress, or in clinical populations. Future research should therefore further explore the impact of stress and continue to investigate sex differences in the cortical processing of emotion and emotion regulation controlling for menstrual phase with non-clinical, sub-clinical, and clinical populations.

10.6.4. Assessment of Menstrual Phase

This program of research involved investigation of only the early follicular and midluteal menstrual phases. These phases were deliberately selected in order to provide an exemplar of low estradiol and low progesterone (early follicular phase, day 1-7) and an exemplar of high estradiol and high progesterone (midluteal phase, day 18-24) (Nillni et al., 2011; Sacher et al., 2013). Consequently, to investigate the impact of high estradiol levels separately from that of high progesterone levels, an optimal design for future research would be to examine all phases and time intervals during the menstrual cycle within the same study as this would allow low/high estradiol and progesterone differences to be examined. The use of between-subjects designs in the three studies in the thesis may have yielded an underestimation of differences between menstrual phases as a result of inter-individual variability between groups (Adolf, Schuurman, Borkenau, Borsboom, & Dolan, 2014; Fields, 2009). Hence, an optimal design for replication studies is a within-subjects design using a larger participant sample to allow testing of women across all the different phases of their menstrual cycle which would permit inter- and intra- individual differences to be controlled. Further, a within-subjects design would allow individual differences to be investigated using procedures such as linear regression analysis.

Classifying women by menstrual cycle phase defined on the basis of self-report or indirect criteria, such as changes in basal body temperature, is undesirable as there are large inter-individual differences in the hormone concentrations attained at each phase, and because self-reports of menstrual cycle phase are known to be unreliable (Becker et al., 2006). The variability that arises from fluctuating hormone concentrations associated with the menstrual cycle can thus be reduced by directly measuring sex hormones at the time of study and classifying women into groups accordingly (Hampson, 2002). Hence, hormone levels were directly measured in Studies 2 and 3 by way of salivary analysis. As discussed by Becker et al., blood serum analysis is a commonly used method for measuring hormone concentrations in both research and clinical settings, however saliva-based assay have various advantages. In particular, assays of blood hormone concentrations calculate the total hormone in blood, while salivary assays calculate the unbound, or more accurately the bioavailable fraction, of a hormone (Becker et al.; Quissell, 1993). As a result, salivary assays produce a valuable index of precisely that fraction of the hormone that exerts biological effects.

Salivary assay analysis were completed for both progesterone and estradiol data, but unfortunately the estradiol data in Studies 2 and 3 could not be statistically analysed due to artefact (i.e., meaningless due to low levels). The low estradiol levels observed were not due to contraception use as only three women (out of 57) in these studies were on hormonal contraceptives at time of testing. These women were tested on the sugar pill during menstruation and were included in the early follicular group, and excluding their data did not alter any analyses at all upon re-analysis of all data sets. As hormonal contraceptive use does not explain the low estradiol levels recorded, we can only conclude that this is due to potential artefact during storage despite following standardised data collection, storage, and assay protocols, or possibly due to low sensitivity of our standardised assay protocols. Due to the necessity of collecting different menstrual phase groups, data collection occurred over a 12 month period of time and this may have led to some deterioration in the saliva samples that impacted on estradiol values.

Alternatively, because measurement of only the free or bioavailable fraction of hormones is available in saliva as discussed above, the concentrations are often near or below the lower detection threshold of standard immunoassays (Becker et al., 2006). As 17β-Estradiol is technically difficult to measure in saliva (Becker et al., 2013), this may explain the low levels of estradiol obtained from salivary assay analysis in Studies 2 and 3. Although progesterone levels were found to be within the expected range for early follicular and midluteal women (Healthscope Functional Pathology Manual, 2011), given the inability to analyse estradiol, we were unable to examine if the obtained findings are due specifically to the effects of estradiol or progesterone. Future studies should use blood samples to measure sex hormones given methodological inconsistencies in previous research with respect to the measurement of sex hormones and classification of women into menstrual cycle phases and the current inability to examine salivary estradiol data. Blood samples would allow more reliable estimates of estradiol and introduce standardised methods to confirm menstrual cycle and ovulation of participants. This would then permit the explicit impact of estradiol and progesterone on ERPs to be further investigated.

10.6.5. Menstrual Phase and Mood

Previous studies have demonstrated an impact of mood on sex differences in the cortical processing of emotional information, as N2 and P3 amplitudes have been found to be larger to unpleasant stimuli in depressed participants, particularly women relative to men (e.g., Campanella et al., 2012; Rossignol, Philippot, Crommelinck, & Campanella, 2008). Evidence associating mood and anxiety with altered emotional processing across the menstrual cycle has also been reported (Nillni et al., 2011; Nillni, Pineles, Patton, Rouse, Sawyer, & Rasmusson, 2015; Sundström Poromaa & Gingnell, 2014). More specifically, studies examining the relationship between menstrual cycle and mood have consistently reported that negative affect and greater levels of anxiety and depression are experienced with higher frequency and severity during the midluteal phase of the menstrual cycle relative to other phases of the menstrual cycle (Cockerill et al., 1994; Epperson & Hantsoo, 2014; Freeman et al., 1996; McLean & Anderson, 2009; Schwartz et al., 2012; Sundström et al., 2014; Van Goozen et al., 1997). However, participants who reported a history or current experience of psychiatric disturbance including anxiety, depression and premenstrual dysphoric disorder were excluded from the three studies in this thesis. Further, we found no differences in self-reported mood in Study 1 (as measured by the POMS) or in depression, anxiety or stress (as measured by the DASS) between women and men, or across menstrual phase groups in Studies 2 and 3. This indicates that mood did not influence the obtained behavioural or ERP findings in the current studies. However, the lack of clinical findings may be related to the POMS and DASS being longer-term measures (i.e., presence of a symptom over the previous week). Thus, we might have obtained different findings if an acute measure of mood and anxiety and a psychophysiology measure had been used. Futher, there was a floor effect in the data for the DASS anxiety subscale as our participants were non-clinical and did not report the experience of much anxiety. Therefore we can not really draw conclusions from this data, and future research needs to assess possible relationships between ERP component amplitudes, sex hormones, and anxiety using clinical samples.

In addition to mood, sex differences in personality traits have been reported, with research revealing that men exhibit higher levels of alexithymia (inability to recognise or discriminate emotions) than women (Campanella et al., 2012; Levant, Hall, Williams, & Hasan, 2009). Further, although we did not assess for empathy or emotional intelligence ability in participants in the current program of research, women have been shown to have higher levels of empathy and emotional intelligence than men (Baron-Cohen, 2010; Hall &

Schmid-Mast, 2008; Kret & De Gelder, 2012; McClure, 2000; Perry et al., 2013; Singh, 2002), and a relationship between increased empathy and greater emotion recognition in women has been established (Rueckert & Naybar, 2008). For example, as compared to men, women have been found to be more cortically reactive to painful stimuli (Han et al., 2008b), to emotional (relative to neutral) stimuli depicting humans rather than scenes (Althaus et al., 2014; Proverbio et al., 2009), and to both highly and moderately unpleasant stimuli depicting human suffering (Luo et al., 2014), with such results seen as evidence that women are more empathic than men. Moreover, and of key relevance to the current thesis, emotional intelligence is regarded as a crucial component of emotion regulation (Mayer & Salovey, 1997), as low emotional intelligence ability is considered a key mechanism underlying emotion dysregulation in various psychopathologies including anxiety (Davidson, 2002; Phillips, Ladouceur, & Drevets, 2008).

The influence of empathy on emotion processing has been found to vary with menstrual cycle phase, as increased emotion recognition and responsiveness to unpleasant stimuli in midluteal women relative to follicular women has been demonstrated (Derntl, Hack, Kryspin-Exner, & Habelb, 2013). Hence, the generally enhanced visual reactivity exhibited by midluteal women in this thesis may be reflective of higher empathy capacity in the components of emotion recognition and responsiveness. Furthermore, midluteal women’s greater difficulty in suppressing their emotional response to unpleasant stimuli, as compared to men and early follicular women, may reflect poorer ability in the emotion regulation components of empathy and emotional intelligence (Mayer & Salovey, 1997).

It would be interesting to examine whether different results would be obtained in depressed or anxious participants, or in participants with low- or high- alexithymia, empathy, or emotional intelligence traits. Future research could therefore investigate cortical reactivity in emotion processing and regulation controlling for the impact of menstrual phase while considering mood, alexithymia, empathy, and emotional intelligence. Additionally, as sex hormones (Becker et al., 2006; Nugent et al., 2012; Walf, Koonce, & Krye, 2015) and anxiety and mood symptoms change across the lifespan (Kessler et al., 2005; Mezuk & Kendler, 2012; Wuthrich, Johnco, & Wetherell, 2015), and the current program of research was conducted with adults aged 18-33 years (Study 1) and 18-44 years (Study 2 and 3), future research could assess emotion processing and emotion regulation in different age groups while also controlling for the impact of menstrual phase (and possibly menopause) and mood.

We focussed on the relatively narrow topic of electrophysiological differences during emotion processing and emotion regulation, whilst controlling for the impact of menstrual phase. This focus of research was chosen due to the failure of existing literature to examine the menstrual phase effects on the processing and regulation of emotion. However, this does not discount the potential role of other factors involved in these processes such as help-seeking, societal role expectations, emotional and mental health literacy, and different manifestation of pathology in terms of symptoms (internal and external). For example, women have been shown to be more likely to seek help for anxiety or mood conditions while men tend to self-treat their disorders through substance abuse (Clement et al., 2015; Lynch, Long, & Moorhead, 2016; Oliffe & Phillips, 2008). Further, when considering social, cultural, and environmental expectations, research has demonstrated that there are differences between men and women according to socialisation, concepts of masculinity and femininity, perceived stigma, and socially accepted norms related to the experience and expression of emotion (Addis & Mahalik, 2003; Jorm, 2000; Lynch et al.; Vogel, Heimerdinger-Edwards, Hammer, & Hubbard, 2011). Future research should thus attempt to measure such societal variables to identify the relative size of effects due to biological versus these other societal factors as it may be that biological differences (in this case electrophysiological reactivity and hormonal influences) are small relative to societal factors.

10.6.6. ERP Component Measurement

There are three commonly accepted approaches to measuring ERP component amplitudes. First, peak amplitude which refers to the amplitude at the time point when a component reaches its minimum or maximum. Second, mean amplitude is the averaged amplitude across all time points within the time window specified for a component. Third, peak-to-peak amplitude refers to the amplitude of one peak relative to an adjacent peak (Fabiani et al., 2000; Handy, 2005; Kam & Handy, 2015). As discussed by Kam and Handy, the decision of whether to examine peak amplitude or mean amplitude measurement is determined by various factors such as the presence of noise and artefact in the data and whether an ERP component has a clear peak. When ERP waveforms contain distinct peaks, a peak amplitude measure can be derived with little uncertainty as to whether the measure accurately encapsulates the peak. However, ERP components can also be characterised by a flatter or more heterogeneous shape leading to ambiguity in whether a peak amplitude measure can accurately capture the component peak. When ERP components do not have a distinct peak or spread across a wide time window, it is recognised that mean amplitude should be used (Fabiani et al.; Handy; Luck, 2005). Further, as peak amplitude measures are sensitive to artefact/noise, mean amplitude is preferable when there is artefact in the electrophysiological data being examined (Fabiani et al.; Handy).

As well-validated techniques (Compumedics Neuroscan, 2006; Semlitsch et al., 1986) were used to estimate and remove noise and artefact in the obtained electrophysiological data in this thesis, the presence of artefact was absent or at worst minimal. The stringent data cleaning processes thus reduced the need for mean amplitude measurement to be used. Consequently, in accordance with ERP quantification guidelines, peak amplitudes of the P1, N1, N2, and P3 components were used in the current program of research as distinct peaks were observable indicating that peak amplitude measurement was appropriate (Fabiani et al., 2000; Kam & Handy, 2015). However, mean amplitude rather than peak amplitude measurement was used for the LPP component as the LPP does not form a distinct peak and extends across a fairly broad time interval (Fabiani et al.; Kam & Handy). Furthermore, in addition to established ERP guidelines, our decisions to analyse peak or mean waveforms were consistent with previous literature which has likewise examined the peak amplitudes of the P1, N1, N2, and P3 components and the mean amplitude of the LPP (e.g., Althaus et al., 2014; Feng et al., 2012; Gardener et al., 2013; Li et al., 2008; Lithari et al., 2010; Moser et al., 2010). A P2 component (which represents perceptual processing modulated by attention) was evident in each of the studies. However, it is not standard in the emotion processing literature to measure the P2 component, and subsequently we did not examine P2.

In addition to amplitude, ERP components can also be characterised according to component latency which is seen to reflect the speed and relative timing of perceptual, cognitive, and/or motor processes (Handy, 2005; Kam & Handy, 2015). While ERP component latency is a commonly used measurement, we did not analyse differences in ERP latencies as the two key theories of emotion processing (motivational model and negativity bias hypothesis) underlying the foundation of this thesis and which were used to guide our hypotheses and subsequent analyses in Studies 1 and 2 make competing predictions in terms of the amount of emotion processing (reflected in ERP amplitude). More precisely, these models make predictions regarding levels of attention and emotional reactivity in response to emotional stimuli and the resulting influence of heightened attention and reactivity on the magnitude of processing with respect to the strength of activation of appetitive and aversive systems. Similarly, although postulating differences in regulation strategy effectivess according to the emotion generation stage when the strategy is applied, the process-specific timing hypotheis informing the anticipated findings and analyses in Study 3 is concerned with the intensity an emotional response has reached before regulation attempts are initiated as heighted reactivity leads to impairments in later emotion regulation. Hence, analysis of data in this program of research did not examine latency as we were interested in the extent of cortical processing to the experimental stimuli rather than the speed of emotion processing. Moreover, as we utilised passive viewing tasks in Studies 2 and 3, which did not require overt responses, we did not consider that latency effects would be captured. To look at latency effects in terms of biased cortical processing an attention bias task, such as a dot probe task, would need to be employed.

In addition to the theoretical models guiding the current thesis, our decision to focus on amplitude rather than latency differences was influenced by the number of ERP components which were examined and is also in accordance with a majority of recent studies using ERPs to examine emotion processing and emotion regulation which have examined amplitude only (e.g., Althaus et al., 2014; Galli et al., 2011; Gardener et al., 2013; Groen et al., 2013; Jin, Yan, Zhang, Jiang, Tao, & Zheng, 2013; Lin et al., 2014; Luo et al., 2014; Meng et al., 2009; Pfabigan et al., 2014; Raz et al., 2014; Syrjänen & Wiens, 2013; Wiens & Syrjänen, 2013), including the Moser et al. (2010) study which we were extending in Study 3 by controlling for the impact of menstrual phase. While ERP amplitude was investigated in the current thesis, we do however acknowledge that in addition to amplitude effects emotional reactivity can be considered in terms of priority processing given that there is evidence to suggest faster processing in early ERP components to unpleasant stimuli (e.g., Doallo, Cadaveira, & Rodriguez-Holquin, 2007; Pizzagalli, Koenig, & Regard, 1998; Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Vuilleumier & Pourtois, 2007). Future ERP and emotion research should therefore also consider latency as an important index to measure. In addition, future research would benefit from combining ERP and fMRI methods to overcome the spatial limitations of ERPs and the temporal limitations of fMRI.

Cramer et al. (2016) has recently raised the critical issue that exploratory use of the commonly used repeated-measures ANOVA harbors a multiple-comparison problem due to the increased probability of Type 1 errors. This multiple-comparision problem and the risk of Type 1 errors is problematic in psychology research as most studies to date fail to correct for it. Indeed, Cramer et al. highlight that repeated-measure ANOVA is one of the most common and popular statistical procedures used in psychological research, however, the results of a detailed literature review demonstrated that less than 1% of existing research which has employed repeated-measure ANOVA has corrected for multiple comparisons. Ways in which the problem of multiple-comparisions is ignored is by the use of exploratory rather than confirmatory research which involves the failure to specify detailed hypotheses a priori and by investigating multiple experimental factors simultaneously.

Whilst we had applied Sidak post-hoc to control for multiple comparisons within each study factor, however this does not control for the number of factors which may have inflated the potential for Type 1 error. To minimise the likelihood of Type 1 error we limited the number of factors analysed. For example, we did not analyse for hemispheric or coronal effects as there was no compelling evidence of laterality differences. We also reported Cohens *d* effect sizes to help offset the risk of Type 1 error and so that the actual magnitude of effects was evident. Although we attempted to control for number of factors we still had three or four factors in each ERP component analysis which can increase the likelihood of Type 1 error (Cramer et al., 2016). The number of factors investigated was informed by the hypotheses and by the exploratory nature of the data, however future research should aim to more tightly control Type 1 error.

In line with Cramer et al., there are a number of strategies researcher may use to reduce the problem of Type 1 error in the future. Strategies include specifying exact hypotheses and therefore conducting confirmatory rather than exploratory analyses and examining only one factor at a time (e.g one ERP component). Using an omnibus *F* test which pools the sums of squares and degrees of freedom for all main effects and interactions into a single *F* statistic can be helpful although it is important to keep in mind that an omnibuss *F* test does not control for Type 1 error under partial null conditions. Maintaining familywise error rate less than or equal to 5% probability is important and Bonferroni procedures can be helpful to achieve this. In addition to the regular Bonferroni correction, a sequential Bonferroni method (e.g., Bonferroni-Holm correction) allows control over the familywise error rate by evaluating each null hypothesis, from one associated with the smallest to the one associated with the largest *p* value, against an alpha level that is adjusted in order to control for the inflated probability of a Type 1 error. However, while adequately controlling for the probability of a Type 1 error, sequential Bonferroni correction has been argued to reduce power to find an experimental effect. An alternative to controlling familywise error rates may be to instead control the false discovery rate, which is the expected proportion of erroneous rejections of the null hypothesis among all rejections of the null hypothesis, using procedures such as the Benjamini-Hochberg correction. Another effective method to mitigate the multiple-comparison problem is pre-registrtion of research studies which requires researchers to specify their hypotheses and analysis plans prior to the data being collected. Other ways to reduce Type 1 errors is to control for study-wise errors and to conduct studies with independent samples.

The issues described above have only recently becoming widely acknowledged, and as such ERP data is plagued with issues associated with the multiple-comparision problem, which may therefore be an alternative explanation for inconsistency of data or be a contributing factor alongside menstrual phase not being controlled for. Studies in the future should strive to incorporate more stringent methods for controlling for the multiple-comparisions problem and associated potential for Type 1 errors, with such considerations leading to improved ERP research and thus progression of the discipline of psychology research.

10.7. Implications of the Program of Research

The finding that midluteal menstrual phase modulates early preconscious processing and suppression capacity has major implications for both clinical research and practice. The results of the current program of research emphasise the importance of, and need for, emotional neuroscience studies to consider menstrual phase when examining sex differences in the cortical processing and regulation of emotion, and when examining visual processing in general. Specifically, researchers studying sex differences should be mindful of variations in endogenous sex hormones that may be of relevance to variables under investigation, and should thus actively control for the influence of menstrual phase by determining which menstrual cycle phase female participants are in on the day of testing. Given variation in the timing and concentrations of sex hormones across women during different phases of life (Becker et al., 2006; Epperson & Hantsoo, 2014; van Veen et al., 2009), direct hormone concentration measurement is required, as this allows expected hormone changes to be verified and the accurate classification of women into particular menstrual phases to be confirmed. Following measurement of sex hormones and confirmation of accurate menstrual phases, researchers must take into consideration their possible effects on obtained behavioural, physiological, and cortical findings.

Heightened emotional reactivity and deficits in emotion regulation are increasingly being recognised as characteristic of most psychiatric disorders including anxiety (Aldao et al., 2010; Cisler & Koster, 2010; Gross, 2012; Gross & Jazaieri, 2014; Kring & Sloan, 2010; Nolen-Hoeksema, 2012), in addition to depression (Nolen-Hoeksema, Wisco, & Lyubomisky, 2008), borderline personality disorder (Lynch, Trost, Salsman, & Linehan, 2007), eating disorders (Lester, Keel, & Lipson, 2003; Polivy & Herman, 2002), and substance abuse (Sher & Grekin, 2007), with prevalence rates of each of these disorders significantly higher in women relative to men. Investigating the cortical underpinnings of sex differences controlling for menstrual phase thus has immense significance for understanding the mechanisms underlying sex differences in the onset, prevalence, severity, and progression of anxiety and a range of other psychiatric conditions.

When we examined sex differences in emotion processing factoring in menstrual phase, we did not confirm current models (using ERPs) of a negativity bias in women or of greater female emotionality in general. Rather, we found generally enhanced preconscious visual processing in midluteal women which appeared concurrently with impaired subsequent emotion regulation processing, as reflected by midluteal women’s reduced capacity to suppress emotional response to unpleasant stimuli. This supports the predictions of the process-specific timing model (Sheppes & Gross, 2011). In sum, our data support the idea that women, particularly midluteal women, may be more vulnerable to anxiety because they tend to be more reactive to emotional stimuli and are less effective in down-regulating with suppression their emotional responses.

There is increasing recognition that clinical interventions benefit when they are informed by empirical understanding of emotion processes. Hence, we speculate that the findings of the current thesis may have implications related to the development and application of clinical interventions targeted at the aversive emotional, psychological, physical, and social outcomes resulting from heightened emotional reactivity and dysregulation of emotion.

Knowledge of emotion regulation processing has been applied during the development of novel clinical interventions for the treatment of anxiety (Berking & Wupperman, 2012; Sheppes & Gross, 2012). For example, more recent formulations of cognitive-behavioral interventions, such as dialectical behaviour therapy, have explicitly incorporated modules that address emotion reactivity, affect tolerance, and skills training in emotion regulation (Linehan, 2013). However, further research is still required as we have shown that early reactivity impairs the effectiveness of emotion regulation strategies, and we have demonstrated modulation of emotion processing and suppression regulation associated with the midluteal menstrual phase. Additionally, reappraisal and suppression are among the most commonly investigated regulation strategies. Additional research investigating the impact of early reactivity on, and sex differences in, reappraisal and suppression capacity, in addition to alternative emotion regulation strategies while also controlling for the impact of menstrual phase is therefore needed.

Despite empirical evidence of the emotional consequences of cognitive reappraisal and suppression, far less is understood about the brain-behavioural mechanisms underlying psychopathology and modulated by clinical interventions. The current study elucidates the differential impact of two distinct emotion regulation strategies on brain-behavioural processes. While hyper-reactivity of limbic systems that detect and experience emotion has been reliably observed in many psychiatric conditions (such as anxiety), our findings characterise the temporal features of bottom-up (emotional reactivity) and top-down (regulatory) brain-behavioral mechanisms that are common targets of pharmacological, psychotherapeutic, and direct brain stimulation interventions.

It may be informative to characterise brain-behavior relationships during emotion reactivity and regulation (i.e., reappraisal and inhibitory cognitive control functioning) in clients with histories of anxiety disorders. This may enhance our ability to match clients to specific treatment modalities that more directly address their emotion dysregulation profile. This matching would also assist clinicians to determine empirically how much and for how long different interventions modulate brain-behavioral systems, in addition to considering the influence of menstrual phase on emotion processes. Further, given that women displayed poorer regulation capacity during the midluteal phase, this would suggest that the timing of intervention components be matched to the menstrual cycle of women. For example, emotion regulation skills should not be taught or developed in female clients during the midluteal phase given the reduced likelihood of success of down-regulation of emotion during the midluteal phase.

Given the menstrual phase effects that we observed, we suggest that the impact of sex differences and menstrual phase form an essential part of psychoeducation in clinical interventions, particularly for anxiety management focused treatments and couple and family based psychotherapy interventions. Finally, our finding that women, particularly midluteal women, display generalised enhancement of visual processing (to neutral, pleasant, and unpleasant stimuli) may be important to guide development of treatment in the future. Women may utilise positive emotions to assist them to down-regulate their negative emotions to a greater extent than men. This suggestion is consistent with evidence showing that women use positive-refocusing as a coping strategy to a greater degree than men (Garnefski, Teerds, Kraaij, Legerstee, & van den Kommer, 2004). If this is the case, clinical interventions which guide clients toward reducing their overall arousal state, or use neutral as a target state, may be less effective in women, especially women in the midluteal phase of their menstrual cycle.

When thinking about what the current findings mean for clinical practice, there is clearly a need for a better understanding of emotional reactivity and emotion regulation. Such an understanding must include identification of the mediating effects of sex hormones on anxiety symptoms as such an understanding has important implications for prevention, assessment, treatment, and research (Nillni et al., 2011), in addition to providing insight into hormonal disorders such as premenstrual dysmorphic disorder and gender dysmorphic disorder.

10.8. Conclusion

This thesis reports a program of research that examined the impact of sex differences on emotional processing and emotion regulation while controlling for menstrual phase. Several potential mechanisms were proposed to underlie the greater prevalence of anxiety in women relative to men in the opening chapters of the thesis. One mechanism was that women display increased emotional reactivity, and we queried whether this heightend reactivity was specific to unpleasant stimuli or to emotional stimuli in general. Alternatively, either combined with greater reactivity or as a unrelated mechanism, we suggested that women have an impaired capacity to regulate their emotional responses to unpleasant stimuli and/or their emotional states than do men. Evidence from Studies 2 and 3 indicate that both mechanisms may be involved, however an important distinction was revealed.

Whilst we found behavioural evidence for a negativity bias in women, we did not find clear electrophysiological support of the proposed negativity bias, or of enhanced processing of emotional stimuli in general in women. Rather, as reflected by larger P1 and N1 amplitudes, we found novel evidence for a generalised enhancement of preconscious visual processing (to both emotional and neutral images) associated with the midluteal phase of the menstrual cycle, and we tested whether this early enhanced visual processing impacted on later emotion regulation in the final study. We found that women in the midluteal phase displayed enhanced preconscious visual processing (P1 and N1) in addition to increased N2 amplitude during suppression instruction, together with greater effort and distress during suppression, suggesting difficulty with suppressing cortical responses to unpleasant stimuli. The diminished ability of women to suppress negative emotional processing may elucidate a mechanism underlying the prevelance of anxiety disorders and represent a possible risk factor for the development of anxiety disorders for which women are more susceptible as compared to men. This finding that the suppression effect is particularly significant during the midluteal phase of the menstrual cycle suggests that women may have an increased risk of emotional dysregulation during the later stages of their menstrual cycle when progesterone levels are high. The current research produced novel and crucial evidence which highlights the importance of controlling for the powerful influence of menstrual phase when investigating sex differences in the cortical processing of both neutral and emotional stimuli, and of both early automatic and later emotion processing and emotion regulation processes.

CHAPTER 11: REFERENCES

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CHAPTER 12: APPENDICES

Appendix A: Summary of Key Thesis Findings

Appendix A

Summary of the Key Thesis Findings

Study and Research Question	Chapter	Findings	Conclusion
Study 1 Will women display greater processing of emotional stimuli in general (motivational model) or to unpleasant stimuli specifically (negativity bias hypothesis)?	7	• Women rated the unpleasant stimuli as being significantly more arousing than did men • Women: larger N2 amplitudes to neutral and unpleasant stimuli compared with pleasant stimuli • Men: greater N2 amplitude to neutral compared to pleasant and unpleasant stimuli, with unpleasant stimuli eliciting larger amplitude than pleasant stimuli. • P3 amplitude was greater to pleasant and unpleasant stimuli relative to neutral stimuli regardless of sex. • LPP amplitudes greater to emotional relative to neutral stimuli for women and men during the dual-task, with LPP amplitudes to all valences larger in women than men	Support for the motivational model during late (P3, LPP) processing across women and men No ERP support for the negativity bias hypothesis
Study 2 Is menstrual phase associated with the negativity bias, motivational model, or to enhanced visual processing in general?	8	• Early follicular and midluteal women rated the low-arousing unpleasant stimuli as significantly more unpleasant and arousing than did men, and the high-arousing stimuli as more unpleasant than did men • Midluteal women displayed enhanced P1and N1 amplitudes to all visual stimuli relative to men • No sex or menstrual phase differences during later (N2, P3, LPP) processing • P3 and LPP amplitudes were greater to highly-arousing unpleasant stimuli relative to the other stimuli conditions	Relative to men, midluteal women have enhanced early visual processing (P1, N1) Support for the negativity bias hypothesis during late (P3, LPP) processing across women and men No ERP support for the motivational model
Study 3 How will menstrual phase impact on t early preconscious emotional reactivity, early conscious attention allocation, and later conscious emotion regulation	9	• Early follicular and midluteal women reported more distress than men, and midluteal women reported more effort when suppressing their emotional responses than men • Increased N2 amplitude during suppression in midluteal women compared to men • Midluteal women exhibited larger P1 and N1 amplitudes relative to men during reappraisal and suppression • No sex or menstrual phase differences during late (P3, LPP) processing	Relative to men, midluteal women have enhanced early visual processing (P1, N1) Women are significantly less able than men to suppress cortical processing of unpleasant stimuli (N2)

Appendix B: IAPS Normative Data and the Mean Valence and Arousal Ratings for Stimuli Presented in Study 1.

Appendix B

IAPS Normative Data and the Mean Valence and Arousal Ratings for Stimuli Presented in Study 1 for Women and Men

IAPS Number	Mean Valence				Mean Arousal			
	IAPS Women	Women	IAPS Men	Men	IAPS Women	Women	IAPS Men	Men
Neutral								
5500	5.34 (1.49)	5.15 (0.93)	5.49 (1.67)	4.80 (0.70)	3.18 (2.25)	1.55 (1.57)	2.82 (2.58)	1.30 (0.98)
5510	5.10 (1.35)	5.00 (0.00)	5.20 (1.52)	4.95 (0.22)	2.87 (2.09)	1.70 (1.38)	2.78 (2.29)	1.30 (0.80)
5520	5.39 (1.21)	4.90 (0.45)	5.28 (1.74)	4.95 (0.22)	2.95 (2.22)	1.45 (1.10)	2.95 (2.63)	1.40 (1.10)
5530	5.44 (1.57)	5.00 (0.32)	5.33 (1.64)	4.95 (0.22)	2.87 (2.12)	1.35 (1.09)	2.87 (2.47)	1.40 (1.23)
5531	5.07 (1.38)	4.85 (0.49)	5.24 (1.54)	4.60 (1.10)	3.80 (2.07)	1.45 (1.45)	3.60 (2.15)	1.30 (0.80)
5532	4.99 (1.66)	4.95 (0.22)	5.43 (1.72)	4.95 (0.22)	3.58 (2.22)	1.30 (0.66)	4.01 (2.18)	1.50 (1.32)
5533	5.49 (1.01)	4.95 (0.39)	5.12 (1.60)	5.05 (0.22)	3.17 (1.85)	1.70 (0.39)	3.08 (2.02)	1.60 (1.35)
5534	4.96 (1.27)	4.75 (0.64)	4.71 (1.60)	5.05 (0.22)	3.40 (1.85)	1.40 (1.23)	2.88 (2.18)	1.50 (1.05)
7255	5.13 (1.24)	5.05 (0.22)	4.98 (1.10)	5.35 (0.99)	3.41 (1.92)	1.65 (1.42)	3.29 (2.09)	1.75 (1.33)
7260	7.31 (1.83)	6.20 (1.97)	7.10 (1.43)	6.00 (1.08)	5.31 (2.22)	3.80 (2.31)	4.88 (2.16)	2.90 (1.48)
7281	6.66 (1.72)	5.90 (0.91)	6.13 (1.25)	6.15 (1.23)	4.49 (2.42)	3.10 (1.80)	4.33 (2.10)	4.30 (2.16)
7285	5.99 (1.81)	5.15 (1.42)	5.30 (1.23)	5.05 (0.89)	4.08 (2.37)	2.15 (2.18)	3.52 (1.74)	2.35 (1.69)
7290	4.22 (1.46)	4.80 (0.70)	4.62 (1.65)	4.80 (1.44)	4.06 (2.09)	1.70 (1.13)	3.56 (2.03)	2.50 (1.79)
7300	5.70 (1.32)	5.05 (0.22)	5.54 (1.05)	5.10 (0.31)	3.33 (1.95)	1.60 (1.43)	3.12 (2.01)	1.70 (1.26)
7340	6.87 (1.63)	6.70 (1.56)	6.40 (1.61)	6.50 (1.28)	3.69 (2.64)	4.25 (2.55)	3.69 (2.53)	4.00 (2.32)
7351	6.06 (1.60)	5.85 (1.14)	5.57 (1.73)	5.80 (1.24)	4.38 (2.41)	3.95 (2.04)	4.11 (2.15)	3.35 (2.18)
7352	6.12 (2.21)	5.65 (0.88)	6.27 (2.22)	5.80 (1.11)	4.58 (2.44)	3.30 (2.20)	4.57 (2.48)	2.90 (1.94)
7354	5.36 (1.83)	5.00 (0.00)	5.72 (1.41)	5.05 (0.22)	3.90 (2.20)	1.45 (0.83)	3.50 (2.18)	2.00 (1.59)
7365	4.96 (1.60)	4.90 (0.64)	5.60 (1.45)	5.25 (0.72)	4.26 (1.89)	2.55 (1.57)	3.90 (1.99)	2.25 (1.77)
7390	6.98 (1.89)	5.40 (0.75)	6.69 (1.56)	5.50 (0.89)	4.73 (2.32)	2.05 (1.40)	4.39 (2.24)	2.45 (1.76)
7405	7.55 (1.76)	6.25 (1.16)	7.08 (1.65)	6.10 (1.33)	6.41 (2.32)	3.30 (2.25)	6.03 (1.84)	3.75 (1.86)
7451	6.49 (2.27)	5.25 (0.88)	6.95 (1.84)	6.35 (1.31)	5.51 (2.09)	2.80 (2.17)	6.34 (1.85)	4.25 (2.13)
7461	6.14 (2.42)	5.00 (1.08)	5.17 (1.87)	5.70 (1.75)	5.38 (2.44)	2.60 (1.64)	4.86 (1.88)	3.40 (2.04)

Appendix B Continued

IAPS Number	Mean Valence				Mean Arousal			
	IAPS Women	Women	IAPS Men	Men	IAPS Women	Women	IAPS Men	Men
Neutral *(cont)*								
7470	7.18 (1.70)	6.25 (1.12)	6.98 (1.50)	6.50 (1.24)	4.72 (2.20)	3.80 (2.48)	4.54 (2.34)	3.65 (2.13)
7475	6.59 (1.62)	6.35 (1.27)	6.04 (1.67)	6.30 (1.49)	4.28 (2.60)	3.75 (2.07)	4.05 (2.38)	4.25 (2.58)
7477	5.93 (2.27)	5.65 (1.09)	6.43 (1.52)	6.05 (1.28)	4.91 (2.32)	2.95 (1.88)	4.66 (2.33)	3.45 (2.35)
7484	4.71 (2.13)	5.45 (1.05)	5.31 (1.74)	5.70 (1.30)	4.00 (2.48)	2.85 (1.95)	4.44 (1.79)	3.30 (1.95)
7488	6.06 (2.21)	6.05 (1.19)	6.35 (1.70)	6.10 (1.21)	4.75 (2.58)	3.60 (2.11)	5.17 (2.06)	4.05 (2.44)
7000	5.06 (1.10)	5.00 (0.00)	4.93 (0.35)	5.00 (0.00)	2.15 (1.70)	1.45 (1.05)	2.73 (1.86)	1.55 (1.10)
7001	5.51 (1.16)	5.05 (0.22)	5.05 (1.18)	4.80 (0.90)	3.38 (2.25)	1.40 (1,89)	2.93 (1.98)	1.25 (0.79)
7002	5.03 (0.98)	5.00 (0.00)	4.91 (0.97)	5.00 (0.00)	3.28 (2.16)	1.10 (0.45)	2.99 (1.81)	1.15 (0.49)
7003	5.02 (1.29)	5.00 (0.00)	4.98 (1.11)	5.00 (0.00)	3.20 (2.12)	1.40 (1.10)	2.89 (1.75)	1.45 (1.05)
7004	5.14 (0.59)	5.00 (0.00)	4.89 (0.60)	4.95 (0.22)	1.94 (1.60)	1.70 (1.59)	2.09 (1.75)	1.35 (0.67)
7009	4.89 (0.96)	5.00 (0.00)	4.96 (1.05)	4.95 (0.22)	3.26 (1.96)	1.15 (0.67)	2.69 (1.95)	1.30 (0.92)
7010	4.92 (0.48)	5.00 (0.00)	4.95 (1.43)	5.05 (0.22)	1.97 (1.58)	1.45 (1.10)	1.55 (1.36)	1.25 (0.64)
7012	4.97 (0.87)	5.00 (0.00)	5.00 (1.28)	4.80 (0.77)	2.88 (1.90)	1.15 (0.50)	3.18 (2.00)	1.15 (0.49)
7017	5.22 (1.26)	5.00 (0.00)	5.12 (0.64)	4.95 (0.22)	3.16 (1.94)	1.65 (1.50)	3.05 (2.04)	1.10 (0.31)
7019	5.13 (1.24)	5.00 (0.00)	5.32 (1.06)	4.95 (0.22)	3.29 (1.93)	1.20 (0.52)	3.48 (1.78)	1.70 (1.13)
7025	4.79 (1.10)	5.00 (0.00)	4.46 (1.23)	5.10 (0.45)	2.98 (2.11)	1.40 (1.05)	2.44 (2.27)	1.25 (0.55)
7026	5.41 (1.33)	5.00 (0.00)	5.33 (1.15)	5.20 (0.89)	2.43 (1.73)	1.30 (0.73)	2.92 (2.16)	1.30 (0.92)
7032	4.76 (1.56)	5.05 (0.76)	4.90 (1.32)	4.95 (0.22)	3.47 (1.90)	1.45 (1.19)	2.77 (1.80)	1.55 (1.15)
7035	5.15 (0.84)	5.00 (0.00)	4.81 (1.05)	5.20 (0.70)	2.75 (1.86)	1.15 (0.49)	2.56 (1.80)	1.60 (1.14)
7042	5.37 (1.14)	5.05 (0.22)	5.82 (1.32)	5.25 (0.55)	3.64 (2.41)	1.80 (1.44)	4.61 (1.89)	2.40 (1.70)
7052	5.24 (1.39)	5.20 (0.52)	5.45 (1.25)	4.90 (0.45)	2.57 (1.86)	1.35 (0.99)	3.47 (2.05)	1.20 (0.52)
7080	5.10 (0.88)	5.00 (0.00)	5.43 (1.26)	4.95 (0.22)	2.67 (1.99)	1.55 (1.50)	1.98 (1.63)	1.55 (1.23)
7090	5.44 (1.35)	5.05 (0.22)	4.95 (1.54)	5.10 (1.02)	2.92 (2.15)	1.50 (1.10)	2.30 (1.90)	1.25 (0.64)
7211	4.69 (1.92)	5.00 (0.00)	4.98 (1.57)	5.05 (0.51)	4.54 (2.46)	1.15 (0.49)	3.70 (2.25)	1.25 (0.91)

Appendix B Continued

IAPS Number	Mean Valence				Mean Arousal			
	IAPS Women	Women	IAPS Men	Men	IAPS Women	Women	IAPS Men	Men
Neutral (*cont*)								
7235	5.06 (1.22)	4.95 (0.22)	4.85 (1.13)	5.20 (0.89)	2.94 (2.08)	1.05 (0.22)	2.68 (1.90)	1.15 (0.37)
5020	6.64 (1.69)	5.50 (1.47)	6.00 (1.63)	5.25 (0.44)	2.69 (1.92)	2.15 (1.35)	2.58 (2.29)	1.45 (0.69)
5040	5.38 (1.14)	5.20 (0.41)	5.40 (1.08)	5.20 (0.62)	3.93 (1.87)	2.00 (1.23)	3.46 (1.91)	2.25 (1.74)
5120	4.15 (1.53)	4.85 (0.49)	4.72 (0.93)	4.15 (1.46)	3.24 (2.17)	1.65 (0.99)	2.85 (2.04)	1.70 (1.17)
5201	7.59 (1.50)	6.25 (1.29)	6.41 (1.72)	5.55 (1.45)	3.77 (2.71)	2.40 (1.54)	3.90 (2.24)	1.95 (1.19)
5726	6.28 (1.60)	5.70 (1.03)	6.15 (1.61)	5.20 (0.70)	2.66 (1.85)	2.60 (1.76)	3.10 (2.26)	1.70 (1.13)
5740	5.33 (1.47)	4.95 (0.99)	5.07 (1.27)	5.00 (0.00)	2.79 (2.16)	1.50 (0.83)	2.36 (1.77)	1.35 (0.81)
5750	6.87 (1.91)	5.50 (0.69)	6.33 (1.75)	5.25 (0.91)	2.95 (2.20)	1.75 (0.79)	3.33 (2.30)	2.05 (1.64)
5800	6.51 (1.57)	5.60 (0.75)	6.21 (1.83)	5.40 (0.99)	2.47 (1.80)	2.00 (1.17)	2.54 (2.22)	1.80 (1.24)
5811	7.88 (1.24)	6.60 (1.35)	6.52 (1.65)	5.40 (0.75)	3.12 (2.66)	2.90 (1.80)	3.49 (1.92)	2.05 (1.54)
5814	7.03 (1.67)	6.10 (1.29)	7.36 (1.31)	5.95 (1.23)	4.96 (2.53)	3.10 (2.34)	4.60 (2.19)	3.50 (2.24)
Pleasant								
4460	6.29 (1.56)	6.40 (1.64)	4.77 (1.23)	3.95 (1.99)	5.78 (1.78)	5.60 (2.01)	3.92 (1.99)	2.75 (2.20)
4470	6.75 (1.43)	5.90 (1.12)	4.79 (1.16)	3.90 (1.86)	6.03 (1.76)	4.60 (1.98)	3.31 (2.02)	2.50 (1.79)
4490	6.27 (1.95)	6.25 (1.41)	4.29 (1.31)	3.70 (2.18)	6.06 (1.71)	5.55 (2.24)	2.85 (1.96)	3.15 (2.21)
4503	6.72 (1.49)	6.70 (1.42)	5.13 (1.04)	4.35 (1.93)	5.81 (2.15)	5.25 (2.43)	3.90 (2.14)	2.70 (1.98)
4505	7.20 (1.16)	7.50 (1.10)	4.37 (1.57)	4.20 (1.91)	6.46 (1.77)	6.20 (2.07)	3.83 (2.08)	2.80 (1.96)
4520	6.94 (1.34)	6.55 (1.15)	5.21 (1.21)	3.95 (1.96)	5.69 (2.11)	4.65 (1.93)	3.71 (1.93)	3.20 (2.46)
4530	6.19 (1.93)	6.05 (1.15)	4.46 (1.12)	3.45 (1.99)	5.31 (2.22)	4.40 (2.19)	3.15 (2.06)	3.10 (2.40)
4538	7.04 (1.74)	7.35 (1.18)	4.59 (1.46)	4.40 (2.21)	6.14 (2.27)	6.25 (1.94)	2.90 (1.82)	3.00 (2.29)
4550	6.22 (1.86)	6.60 (1.54)	3.26 (1.69)	3.50 (2.09)	6.24 (2.04)	5.60 (2.28)	3.34 (2.50)	3.10 (2.36)
4561	6.10 (2.00)	7.25 (1.65)	3.82 (1.96)	3.45 (2.11)	5.90 (2.27)	6.40 (2.06)	2.64 (1.95)	3.20 (2.78)
4001	3.58 (1.74)	5.95 (1.19)	7.20 (1.54)	7.30 (1.46)	3.88 (2.13)	4.65 (2.35)	6.81 (1.90)	6.45 (1.99)

Appendix B Continued

IAPS Number	Mean Valence				Mean Arousal			
	IAPS Women	Women	IAPS Men	Men	IAPS Women	Women	IAPS Men	Men
Pleasant *(cont)*								
4002	4.14 (1.82)	5.95 (1.70)	7.69 (1.48)	7.55 (1.73)	3.72 (2.30)	4.65 (2.18)	7.15 (1.81)	7.15 (2.11)
4003	4.30 (1.64)	5.80 (1.67)	6.67 (1.71)	7.05 (1.43)	4.25 (1.98)	4.65 (1.98)	5.94 (1.81)	6.35 (2.32)
4005	4.36 (1.97)	5.85 (1.76)	6.52 (1.58)	6.95 (1.61)	4.28 (1.84)	4.50 (2.12)	5.77 (1.87)	6.25 (2.45)
4006	5.22 (1.30)	6.15 (1.93)	7.35 (1.28)	7.55 (1.36)	4.43 (2.11)	5.30 (2.25)	6.59 (1.86)	6.50 (2.44)
4008	4.60 (1.68)	5.90 (1.65)	7.75 (1.54)	7.95 (1.54)	4.73 (2.09)	4.80 (2.38)	6.94 (1.99)	7.30 (2.20)
4085	4.35 (1.78)	5.85 (1.69)	8.00 (1.14)	8.15 (1.57)	4.68 (2.34)	4.65 (2.25)	7.55 (1.63)	7.75 (1.99)
4090	5.17 (1.36)	5.65 (1.60)	7.64 (1.26)	7.45 (1.32)	4.17 (2.04)	4.35 (2.28)	7.18 (1.30)	6.25 (2.27)
4130	4.16 (1.60)	5.65 (1.63)	7.39 (1.32)	7.65 (1.66)	4.25 (2.09)	4.30 (2.25)	6.64 (1.76)	6.80 (2.33)
4141	4.01 (1.90)	5.90 (1.71)	7.46 (1.59)	7.95 (1.32)	4.00 (2.19)	5.00 (1.97)	6.73 (1.94)	7.65 (1.98)
4142	3.49 (2.18)	5.70 (1.75)	7.55 (1.68)	7.55 (1.82)	4.32 (2.44)	5.10 (1.99)	6.97 (2.04)	7.60 (1.60)
4180	4.21 (1.84)	5.90 (1.71)	8.21 (1.34)	7.85 (1.53)	3.62 (2.36)	4.45 (2.24)	7.43 (1.97)	6.95 (2.48)
4232	4.06 (2.05)	5.45 (1.88)	7.88 (1.10)	7.40 (1.70)	5.06 (2.32)	4.90 (2.20)	7.52 (1.51)	6.90 (2.32)
4235	3.67 (1.82)	5.65 (1.53)	7.29 (1.61)	7.70 (1.42)	3.97 (2.44)	4.90 (2.15)	6.73 (2.33)	7.00 (2.71)
4240	3.73 (1.77)	5.40 (1.69)	7.52 (1.22)	7.25 (1.45)	3.65 (4.79)	4.40 (1.82)	6.54 (2.12)	6.75 (2.51)
4279	4.16 (1.43)	4.80 (1.36)	7.23 (1.25)	6.55 (1.61)	2.89 (1.88)	3.10 (1.80)	6.38 (2.05)	5.85 (2.41)
4290	3.67 (1.60)	5.50 (1.47)	7.61 (1.69)	7.20 (1.54)	4.10 (2.34)	4.70 (2.30)	7.20 (1.87)	6.55 (2.48)
4300	4.19 (1.91)	5.15 (1.69)	7.56 (1.29)	7.70 (1.78)	4.98 (2.13)	4.45 (1.85)	7.23 (1.98)	6.85 (2.37)
4310	4.81 (1.26)	5.55 (1.67)	7.56 (1.53)	7.60 (1.57)	4.23 (1.76)	4.55 (2.19)	6.89 (1.87)	6.85 (2.46)
4320	4.66 (1.21)	5.05 (1.82)	7.48 (1.92)	7.05 (1.50)	3.96 (1.94)	3.60 (1.98)	6.37 (2.09)	6.35 (2.32)
4604	5.71 (1.88)	6.55 (0.99)	6.44 (1.45)	6.90 (1.45)	5.94 (1.86)	5.65 (1.84)	6.33 (1.88)	6.35 (2.13)
4611	6.00 (2.06)	6.70 (1.26)	7.27 (1.25)	7.20 (1.28)	5.58 (2.11)	5.35 (2.08)	6.50 (2.02)	5.80 (2.44)
4647	5.02 (1.52)	6.15 (1.42)	7.25 (1.78)	7.90 (1.37)	5.69 (2.16)	5.95 (2.14)	7.04 (2.19)	7.50 (1.93)
4651	5.15 (1.98)	6.70 (1.30)	7.52 (1.66)	7.70 (1.26)	5.71 (1.96)	5.90 (1.77)	6.96 (1.95)	7.05 (1.70)
4652	5.65 (2.11)	6.45 (1.32)	7.92 (1.06)	7.75 (1.25)	5.98 (2.20)	6.15 (2.08)	7.25 (1.64)	7.70 (1.46)

Appendix B Continued

IAPS Number	Mean Valence				Mean Arousal			
	IAPS Women	Women	IAPS Men	Men	IAPS Women	Women	IAPS Men	Men
Pleasant *(cont)*								
4658	6.08 (2.05)	6.65 (1.76)	7.35 (1.37)	7.40 (1.35)	6.16 (2.17)	6.30 (2.16)	6.89 (2.06)	7.45 (1.36)
4659	6.15 (2.01)	6.50 (1.61)	7.70 (1.64)	7.55 (1.23)	6.47 (2.18)	6.15 (1.95)	7.43 (1.80)	7.55 (1.19)
4660	7.22 (1.40)	6.25 (1.41)	7.63 (1.30)	6.60 (1.43)	6.31 (1.95)	5.00 (2.15)	6.92 (6.69)	5.45 (2.35)
4664.1	4.42 (2.26)	5.70 (1.34)	7.44 (1.97)	7.85 (1.27)	6.06 (1.82)	6.35 (1.98)	7.46 (1.63)	7.40 (1.85)
4668	6.31 (1.70)	6.90 (1.45)	7.34 (1.47)	7.85 (1.23)	6.85 (1.65)	6.85 (1.73)	7.66 (1.45)	7.50 (1.93)
4669	5.18 (2.00)	6.60 (1.50)	6.84 (1.93)	6.95 (1.32)	5.82 (2.40)	5.95 (2.11)	6.44 (2.43)	6.35 (1.79)
4670	6.40 (1.91)	6.80 (1.40)	7.77 (1.05)	7.75 (1.37)	6.42 (2.07)	6.85 (1.76)	7.17 (1.93)	7.30 (1.53)
4672	5.60 (1.85)	6.65 (1.63)	6.44 (2.17)	7.30 (1.34)	6.17 (2.35)	6.30 (1.87)	6.42 (2.40)	6.45 (2.21)
4677	6.63 (1.72)	6.55 (1.73)	6.53 (1.56)	6.80 (1.40)	6.38 (2.03)	5.90 (1.83)	5.97 (2.12)	6.00 (1.78)
4690	6.43 (1.84)	6.20 (1.44)	7.42 (1.96)	7.05 (1.32)	5.79 (2.17)	5.20 (2.02)	6.46 (2.22)	6.60 (1.73)
4693	5.63 (1.91)	6.40 (1.23)	6.92 (1.66)	7.55 (1.28)	6.56 (1.76)	5.80 (1.88)	6.58 (2.11)	7.00 (1.75)
4694	6.22 (1.69)	6.90 (1.41)	7.43 (1.43)	7.65 (1.14)	5.99 (2.09)	6.40 (1.82)	7.10 (1.89)	7.30 (1.75)
4695	6.38 (1.55)	6.35 (1.42)	7.37 (1.31)	7.70 (1.17)	6.25 (2.04)	6.05 (1.88)	7.00 (1.57)	7.45 (1.76)
4800	5.45 (2.28)	6.85 (1.57)	7.43 (1.69)	7.80 (1.36)	6.39 (1.91)	6.95 (1.50)	7.76 (1.33)	7.35 (1.93)
4810	5.98 (2.11)	6.50 (1.61)	7.20 (1.89)	8.00 (1.30)	6.44 (2.05)	6.55 (2.09)	6.89 (2.23)	7.80 (1.24)
5621	7.80 (1.54)	6.60 (1.19)	7.28 (1.22)	6.40 (1.35)	7.00 (2.13)	6.05 (2.33)	6.96 (1.72)	5.55 (2.61)
5622	6.23 (2.08)	5.10 (1.45)	6.44 (1.43)	5.45 (1.40)	5.30 (2.03)	4.55 (1.57)	5.38 (1.89)	4.35 (1.93)
5623	7.26 (1.57)	6.65 (1.46)	7.12 (1.29)	5.95 (1.32)	5.77 (2.36)	5.25 (2.43)	5.56 (2.30)	4.25 (2.25)
5626	6.62 (2.34)	7.05 (1.43)	6.81 (1.75)	6.45 (1.36)	5.98 (2.11)	5.20 (2.19)	6.23 (2.29)	4.65 (2.43)
8030	7.35 (1.86)	6.25 (1.37)	7.29 (1.66)	6.10 (1.07)	7.38 (1.91)	5.75 (2.57)	7.32 (2.16)	4.80 (2.33)
8031	6.75 (1.57)	6.45 (1.43)	6.77 (1.20)	5.95 (1.10)	5.57 (2.23)	5.30 (2.56)	5.60 (2.28)	4.60 (1.76)
8033	7.36 (1.35)	5.65 (1.39)	5.82 (1.25)	5.30 (0.73)	5.55 (2.16)	3.95 (2.19)	4.35 (1.98)	3.00 (1.89)
8034	7.19 (1.63)	6.20 (1.47)	6.90 (1.41)	5.55 (1.10)	6.38 (2.10)	4.35 (2.82)	6.20 (2.24)	3.65 (1.93)
8041	7.48 (1.28)	6.25 (1.37)	5.68 (1.54)	5.65 (1.09)	5.97 (2.23)	4.95 (2.31)	4.92 (2.26)	4.00 (2.13)

Appendix B Continued

IAPS Number	Mean Valence				Mean Arousal			
	IAPS Women	Women	IAPS Men	Men	IAPS Women	Women	IAPS Men	Men
Unpleasant *(cont)*								
3069	1.32 (1.01)	1.05 (0.22)	2.10 (1.66)	1.20 (0.52)	7.33 (2.20)	6.30 (3.35)	6.70 (2.60)	4.25 (3.29)
3071	1.69 (1.14)	1.45 (0.95)	2.06 (1.59)	1.65 (1.31)	7.10 (1.95)	6.00 (3.00)	6.61 (2.13)	3.50 (2.71)
3080	1.33 (0.75)	1.10 (0.31)	1.63 (1.11)	1.45 (0.95)	7.61 (1.81)	6.15 (3.12)	6.84 (2.06)	3.80 (3.02)
3100	1.35 (0.96)	1.30 (0.57)	1.88 (1.14)	1.10 (0.31)	7.02 (2.02)	5.90 (2.86)	5.88 (2.34)	3.60 (2.95)
3225	1.66 (1.20)	1.95 (1.15)	2.06 (1.24)	1.65 (0.99)	6.32 (2.43)	5.50 (2.42)	5.39 (2.41)	3.40 (2.44)
9040	1.50 (0.97)	1.50 (0.69)	1.88 (1.17)	1.65 (1.04)	6.44 (2.00)	5.85 (2.83)	5.10 (2.11)	3.60 (2.85)
9252	1.53 (1.25)	1.65 (0.81)	2.51 (1.78)	1.80 (1.28)	6.93 (2.33)	5.40 (2.62)	6.27 (2.30)	3.95 (2.93)
9253	1.60 (0.99)	1.50 (1.19)	2.51 (1.23)	1.40 (0.99)	5.65 (2.58)	5.95 (2.87)	5.38 (2.16)	3.50 (2.78)
9433	1.35 (0.71)	1.60 (0.82)	2.39 (1.38)	1.65 (0.88)	6.71 (2.27)	5.30 (2.98)	5.00 (2.65)	3.80 (2.91)
3030	1.51 (1.07)	1.55 (0.69)	2.31 (1.87)	1.65 (0.93)	7.13 (1.88)	5.55 (2.89)	6.39 (2.26)	3.80 (2.88)
3101	1.64 (1.04)	1.45 (0.76)	2.23 (1.28)	2.00 (1.08)	5.96 (2.48)	5.45 (2.59)	5.18 (2.38)	3.40 (2.62)
3102	1.22 (0.85)	1.25 (0.55)	1.62 (1.39)	1.35 (0.93)	7.15 (2.48)	6.10 (3.16)	5.88 (2.79)	3.40 (2.84)
3103	1.71 (1.02)	2.30 (1.46)	2.70 (1.40)	1.80 (0.83)	6.60 (2.07)	4.55 (2.31)	5.15 (2.40)	3.25 (2.45)
3110	1.47 (0.89)	2.15 (2.00)	2.10 (1.56)	1.40 (0.68)	6.98 (2.04)	5.55 (2.96)	6.43 (2.26)	3.45 (2.56)
3140	1.50 (0.97)	1.55 (0.61)	2.22 (1.27)	1.60 (0.75)	6.94 (1.68)	5.25 (2.71)	5.68 (2.08)	3.35 (2.58)
3150	1.98 (1.54)	1.15 (0.37)	2.59 (1.56)	1.55 (1.05)	6.94 (2.07)	6.25 (3.23)	6.10 (2.29)	3.85 (3.13)
3170	1.20 (0.57)	1.50 (0.69)	1.77 (1.31)	1.25 (0.44)	7.55 (1.98)	5.85 (3.07)	6.79 (1.93)	3.85 (2.89)
3180	1.67 (0.90)	2.60 (1.14)	2.27 (1.33)	2.20 (1.06)	6.19 (2.24)	3.90 (2.29)	5.17 (2.05)	3.35 (2.23)
3181	2.01 (1.29)	2.30 (1.17)	2.79 (1.54)	1.70 (0.92)	5.16 (2.08)	4.50 (2.26)	4.90 (2.17)	3.10 (2.36)
3185	2.52 (1.52)	2.60 (1.05)	3.29 (1.42)	2.45 (1.32)	5.68 (2.18)	4.10 (2.27)	5.14 (2.16)	3.05 (2.24)
3191	1.68 (1.04)	2.50 (1.24)	2.39 (1.37)	2.10 (1.12)	6.26 (2.05)	4.40 (2.62)	5.45 (2.28)	3.55 (2.35)
3195	1.79 (1.06)	2.05 (1.05)	2.56 (1.38)	2.00 (1.03)	6.42 (2.53)	4.80 (2.51)	6.23 (1.63)	3.35 (2.32)
3213	2.61 (2.03)	1.60 (0.75)	3.63 (1.57)	1.80 (1.28)	6.79 (2.22)	6.05 (2.93)	6.89 (1.55)	4.20 (3.07)
3261	1.70 (1.43)	1.20 (0.62)	1.98 (1.19)	1.25 (0.55)	5.92 (2.60)	5.75 (3.23)	5.51 (2.70)	3.20 (2.55)

Appendix B Continued

IAPS Number	Mean Valence				Mean Arousal			
	IAPS Women	Women	IAPS Men	Men	IAPS Women	Women	IAPS Men	Men
Unpleasant *(cont)*								
3266	1.26 (0.56)	1.10 (0.45)	1.98 (1.28)	1.60 (1.39)	7.43 (1.75)	6.20 (3.27)	5.85 (2.21)	4.75 (2.65)
3400	2.06 (1.77)	1.10 (0.31)	2.67 (2.01)	1.45 (0.95)	7.12 (2.14)	6.00 (3.56)	6.67 (2.29)	3.95 (3.10)
8230	2.11 (1.23)	2.15 (0.99)	4.17 (1.99)	3.20 (1.80)	6.01 (2.16)	5.55 (2.59)	5.75 (2.16)	3.70 (2.43)
9042	2.44 (1.50)	1.75 (0.85)	3.93 (1.98)	1.85 (1.09)	6.38 (2.43)	5.05 (2.72)	5.13 (2.39)	3.25 (2.49)
9405	1.59 (1.02)	1.30 (0.57)	2.09 (1.27)	1.40 (0.82)	6.77 (2.22)	5.75 (3.19)	5.31 (2.38)	3.60 (2.89)
2811	1.74 (1.22)	3.15 (0.99)	2.84 (1.35)	2.95 (1.40)	7.27 (2.10)	4.25 (2.15)	6.31 (2.30)	4.35 (2.64)
3500	1.94 (1.38)	2.50 (1.19)	2.50 (1.24)	2.45 (1.19)	7.26 (2.32)	4.50 (2.26)	6.80 (2.04)	4.10 (2.29)
6210	2.15 (1.42)	3.30 (1.03)	3.73 (1.87)	3.65 (1.23)	6.72 (2.21)	3.60 (1.82)	5.98 (2.03)	2.95 (2.04)
6211	3.00 (2.28)	2.75 (1.07)	4.25 (1.62)	2.75 (1.41)	6.42 (2.11)	3.90 (1.97)	5.38 (2.22)	4.15 (2.46)
6213	2.41 (1.38)	2.45 (0.95)	3.75 (1.39)	3.10 (1.25)	6.22 (2.06)	4.25 (2.20)	5.25 (1.93)	3.45 (2.06)
6231	2.15 (1.46)	2.70 (1.03)	2.98 (1.53)	2.70 (1.17)	6.95 (1.96)	4.54 (2.32)	6.61 (2.31)	4.20 (2.46)
6242	2.24 (1.47)	2.95 (1.18)	3.28 (1.56)	2.95 (1.32)	5.68 (2.35)	4.45 (2.04)	5.09 (2.35)	3.45 (2.28)
6244	2.53 (1.44)	2.95 (0.99)	3.85 (1.93)	3.00 (1.41)	5.72 (2.61)	4.15 (1.84)	5.63 (2.39)	3.70 (2.41)
6260	2.35 (1.45)	2.75 (1.33)	2.53 (1.63)	2.95 (1.43)	6.76 (1.97)	4.20 (2.24)	7.10 (1.90)	3.65 (2.46)
6300	1.94 (1.36)	2.75 (1.07)	3.30 (1.67)	2.80 (1.54)	6.84 (2.16)	3.75 (1.59)	6.37 (1.73)	3.70 (2.20)
6312	2.08 (1.47)	3.10 (1.02)	2.88 (1.48)	2.45 (1.40)	6.83 (2.19)	4.25 (2.22)	5.90 (2.35)	3.35 (2.39)
6313	1.61 (1.22)	2.15 (0.99)	2.43 (1.42)	2.15 (0.99)	7.27 (2.29)	4.65 (2.43)	6.54 (2.11)	3.90 (2.53)
6315	1.72 (1.23)	2.55 (1.15)	2.94 (1.89)	2.15 (1.14)	6.69 (2.57)	4.55 (2.24)	6.04 (2.16)	3.85 (2.76)
6350	1.44 (0.95)	2.35 (0.93)	2.39 (1.42)	2.65 (1.84)	7.52 (1.99)	4.65 (2.08)	7.04 (1.73)	3.60 (1.37)
6510	2.06 (1.28)	2.54 (1.23)	2.86 (1.76)	2.40 (1.05)	7.16 (1.81)	4.85 (2.21)	6.76 (2.33)	3.65 (2.11)
6520	1.59 (1.01)	2.05 (1.32)	2.45 (1.43)	1.60 (0.88)	7.12 (1.72)	5.35 (2.70)	5.85 (2.32)	3.45 (2.40)
6550	2.08 (1.90)	2.35 (1.14)	3.39 (2.63)	2.05 (1.05)	7.20 (1.83)	5.00 (2.29)	6.98 (2.13)	4.25 (2.67)
6560	1.78 (1.23)	2.05 (1.19)	2.57 (1.49)	2.30 (1.46)	6.86 (2.52)	5.25 (2.81)	6.17 (2.28)	4.15 (2.52)
6570.1	2.25 (1.88)	2.20 (1.00)	2.96 (1.50)	2.30 (1.26)	6.37 (2.25)	4.95 (2.40)	5.76 (2.02)	3.65 (2.66)

Appendix B Continued

IAPS Number	Mean Valence				Mean Arousal			
	IAPS Women	Women	IAPS Men	Men	IAPS Women	Women	IAPS Men	Men
Unpleasant *(cont)*								
6821	1.85 (1.31)	2.65 (0.99)	2.96 (1.93)	3.00 (1.26)	6.62 (1.91)	4.45 (1.91)	5.93 (2.10)	3.85 (2.08)
1050	3.02 (1.93)	3.85 (1.84)	3.90 (2.28)	3.60 (1.73)	6.90 (1.82)	4.75 (2.17)	6.84 (1.55)	4.40 (2.46)
1052	2.99 (1.85)	3.55 (1.43)	4.35 (1.56)	3.40 (1.47)	6.89 (2.18)	4.80 (2.12)	5.92 (2.20)	4.10 (2.15)
1112	4.60 (1.61)	4.55 (1.05)	4.38 (1.79)	4.45 (0.99)	4.79 (2.45)	2.50 (2.24)	4.40 (2.44)	3.40 (2.30)
1114	3.43 (2.16)	3.25 (1.48)	4.73 (1.93)	3.75 (1.37)	6.34 (2.19)	4.85 (2.06)	6.33 (2.16)	4.30 (2.27)
1120	3.03 (1.74)	3.35 (1.42)	4.73 (1.75)	3.15 (1.57)	7.20 (1.86)	4.85 (1.90)	6.60 (1.38)	4.50 (2.63)
1201	2.93 (1.81)	3.20 (1.47)	4.27 (1.73)	3.10 (1.48)	6.87 (2.09)	3.95 (2.31)	5.75 (1.99)	3.65 (2.54)
1202	2.98 (1.65)	3.25 (1.48)	4.03 (1.81)	2.50 (1.36)	5.80 (2.47)	3.95 (2.28)	6.20 (1.45)	4.00 (2.58)
1205	3.22 (1.62)	3.05 (1.40)	4.15 (1.78)	3.20 (1.54)	5.94 (2.22)	4.60 (2.48)	5.61 (2.13)	3.55 (2.35)
1220	3.05 (1.81)	3.10 (1.41)	3.88 (1.76)	3.00 (1.65)	5.74 (2.19)	3.90 (1.89)	5.40 (2.50)	3.80 (2.35)
1300	3.41 (1.63)	2.70 (0.98)	4.06 (1.54)	2.75 (1.16)	6.70 (2.04)	5.00 (2.03)	6.90 (1.59)	4.00 (2.51)
1301	3.32 (1.53)	3.55 (0.99)	4.10 (1.71)	3.40 (1.31)	5.91 (1.96)	4.74 (1.37)	5.63 (2.39)	3.65 (2.03)
1302	4.11 (1.88)	3.80 (0.95)	4.38 (1.64)	3.70 (1.59)	6.08 (1.95)	3.85 (1.42)	5.89 (1.79)	3.60 (2.30)
1310	4.05 (1.49)	4.00 (1.65)	5.27 (1.54)	3.60 (1.88)	6.09 (1.96)	4.15 (1.79)	5.89 (1.61)	3.70 (2.54)
1321	3.90 (1.86)	4.00 (1.45)	4.94 (1.71)	3.95 (1.67)	6.85 (1.85)	4.25 (1.71)	6.34 (1.94)	4.20 (2.33)
1525	2.67 (1.74)	2.55 (1.10)	3.55 (1.59)	2.95 (1.43)	6.86 (2.16)	4.80 (2.02)	6.14 (2.31)	4.40 (2.80)
1726	4.34 (2.13)	4.20 (1.54)	5.34 (1.94)	4.40 (1.76)	6.32 (2.14)	5.00 (1.72)	6.13 (2.26)	4.80 (2.61)
1820	4.99 (2.14)	3.75 (1.45)	5.85 (1.83)	3.85 (1.69)	5.91 (2.04)	4.25 (2.15)	5.33 (2.13)	4.60 (2.54)
1930	3.56 (1.90)	3.35 (1.57)	4.12 (1.92)	3.35 (1.46)	6.71 (1.91)	4.80 (1.88)	5.98 (2.24)	4.95 (2.76)
1931	3.57 (2.13)	3.40 (1.35)	4.51 (2.35)	3.75 (1.59)	6.73 (2.23)	4.50 (1.91)	6.88 (1.77)	4.30 (2.43)
1932	2.92 (1.87)	3.30 (1.49)	4.85 (1.89)	3.30 (1.72)	6.73 (2.20)	4.95 (2.11)	6.21 (2.18)	4.35 (2.56)

Note. Standard Deviations in parentheses; IAPS = International Affective Picture System.

Appendix C: Study 1 Analyses.

Appendix C

Mean Stimuli Valence during the Single and Dual Conditions in Study 1 for Women and Men at Relevant ERP Component Sites.

Component (and Sites)	Valence	Women						Men					
		Single			Dual			Single			Dual		
<u>P1</u>		O1	OZ	O2	O1	OZ	O2	O1	OZ	O2	O1	OZ	O2
	NEUT	6.31 (4.50)	4.07 (4.71)	6.23 (4.59)	5.91 (4.78)	2.90 (4.30)	4.96 (4.68)	3.66 (3.97)	2.28 (3.75)	3.97 (4.37)	3.05 (4.08)	2.33 (3.98)	3.47 (4.48)
	PL	7.41 (4.44)	5.78 (4.68)	6.78 (4.23)	6.93 (4.67)	4.63 (4.42)	3.98 (10.37)	4.60 (3.62)	3.48 (3.40)	5.07 (3.67)	4.32 (3.34)	3.26 (3.20)	4.34 (3.54)
	UNPL	6.47 (4.80)	4.14 (4.69)	5.94 (4.57)	6.82 (4.62)	4.54 (4.22)	6.48 (3.91)	4.26 (3.66)	2.97 (3.39)	4.07 (3.97)	3.55 (3.79)	2.39 (3.66)	4.10 (4.17)
<u>N1</u>		F3	FZ	F4	F3	FZ	F4	F3	FZ	F4	F3	FZ	F4
	NEUT	-5.21 (2.43)	-5.23 (3.09)	-4.58 (2.93)	-5.68 (1.82)	-5.98 (2.08)	-5.39 (1.99)	-5.34 (2.64)	-5.49 (2.91)	-5.01 (2.52)	-5.50 (2.89)	-5.76 (2.97)	-5.25 (2.65)
	PL	-5.48 (2.25)	-5.98 (2.98)	-5.19 (2.81)	-5.30 (2.56)	-5.71 (2.87)	-5.02 (2.60)	-5.44 (2.58)	-6.19 (2.85)	-5.51 (2.51)	-5.72 (2.88)	-5.67 (3.14)	-5.26 (2.68)
	UNPL	-6.02 (2.47)	-6.28 (2.68	-5.40 (2.61)	-5.82 (2.32)	-6.37 (2.59)	-5.78 (2.34)	-5.47 (2.65)	-5.85 (2.67)	-5.12 (2.34)	-5.21 (2.76)	-5.28 (3.12)	-4.76 (2.63)
<u>N2</u>		F3	FZ	F4	F3	FZ	F4	F3	FZ	F4	F3	FZ	F4
	NEUT	-6.68 (5.06)	-7.09 (5.97)	-5.78 (5.23)	-6.90 (5.09)	-7.50 (5.29)	-6.01 (4.93)	-6.86 (3.99)	-7.81 (4.26)	-6.33 (3.73)	-7.52 (3.85)	-8.59 (4.55)	-6.99 (3.75)
	PL	-4.57 (4.86)	-5.51 (4.90)	-3.97 (4.86)	-4.08 (4.80)	-4.61 (4.64)	-3.56 (4.15)	-3.95 (4.27)	-4.65 (4.54)	-3.15 (3.92)	-3.16 (4.04)	-3.03 (4.31)	-2.27 (4.54)
	UNPL	-6.99 (5.04)	-7.42 (5.65)	-5.69 (5.31)	-6.49 (5.04)	-6.90 (5.01)	-5.20 (4.25)	-5.62 (5.02)	-6.25 (5.47)	-4.32 (4.52)	-5.35 (4.16)	-5.74 (4.63)	-3.88 (4.10)

Appendix C Continued

		Women						Men					
Component (and Sites)	Valence	Single			Dual			Single			Dual		
P3		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	NEUT	10.38 (5.33)	10.86 (5.06)	10.82 (5.78)	9.65 (4.76)	10.57 (5.28)	10.36 (5.16)	4.66 (2.99)	4.09 (3.90)	5.55 (3.40)	4.56 (3.84)	3.99 (4.40)	5.13 (3.37)
	PL	14.59 (4.72)	16.51 (4.64)	14.53 (5.10)	14.86 (4.62)	15.28 (4.10)	13.70 (4.98)	8.99 (4.30)	10.28 (4.31)	9.77 (3.33)	8.69 (3.77)	9.87 (3.71)	9.05 (3.12)
	UNPL	13.51 (5.09)	14.75 (4.31)	13.50 (4.66)	13.21 (5.70)	14.10 (4.74)	13.27 (4.92)	8.00 (3.42)	8.62 (3.96)	8.23 (2.88)	7.45 (3.02)	7.85 (3.53)	7.84 (2.46)
LPP		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	NEUT	4.17 (4.18)	5.31 (4.40)	3.38 (4.22)	6.47 (3.00)	7.84 (3.56)	5.96 (3.26)	1.07 (3.26)	1.43 (3.61)	.73 (3.16)	1.36 (3.59)	1.83 (3.64)	1.11 (3.18)
	PL	8.41 (4.66)	10.37 (4.93)	6.85 (4.18)	9.56 (3.39)	11.57 (3.90)	8.64 (2.85)	5.03 (4.23)	6.01 (4.45)	4.21 (4.27)	6.07 (3.70)	7.49 (3.61)	5.43 (3.13)
	UNPL	8.76 (4.86)	10.75 (5.02)	7.14 (3.74)	9.65 (3.62)	11.51 (3.74)	8.60 (3.11)	5.46 (4.11)	6.42 (4.16)	4.57 (4.15)	5.42 (4.24)	6.61 (4.17)	4.60 (3.81)

Note. Standard Deviations in parentheses; NEUT = Neutral; PL = Pleasant; UNPL = Unpleasant.

Appendix C

Repeated Measure ANOVA Results for Study 1 Experimental Variables and Variable Interactions for each ERP Component.

Variable		P1			N1			N2			P3			LPP	
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Sex	2.74	.11	.067	.04	.85	.001	.16	.70	.004	24.84	<.001	.395	14.86	<.001	.28
Condition	2.81	.10	.069	.05	.82	.001	.94	.34	.024	1.37	.25	.035	5.28	.03	.122
Valence	7.35	.004	.162	.88	.42	.023	40.47	.00	.52	115.38	<.001	.752	15.12	<.001	.803
Site	16.24	<.001	.299	16.51	<.001	.303	24.46	.00	.392	1.99	.15	.050	32.82	<.001	.463
Sex × Condition	.18	.67	.005	.85	.36	.022	.00	.99	.00	.01	.92	.00	1.28	.27	.032
Sex × Valence	.38	.61	.010	2.91	.06	.071	4.56	.02	.107	.14	.87	.004	.95	.39	.024
Sex × Site	2.26	.13	.056	.21	.80	.006	.01	.98	.00	1.32	.27	.033	2.89	.07	.071
Condition × Valence	2.37	.11	.059	1.93	.15	.048	4.34	.02	.102	.08	.91	.002	2.56	.08	.063
Condition × Site	.67	.45	.017	.81	.43	.02	.81	.41	.021	1.01	.37	.026	1.15	.32	.029
Valence × Site	1.77	.19	.044	.93	.44	.024	4.90	.003	.114	14.52	<.001	.276	27.94	<.001	.424
Sex × Condition × Valence	2.51	.10	.062	.32	.72	.008	.49	.61	.013	.16	.87	.003	2.85	.06	.070
Sex × Condition × Site	1.06	.33	.027	2.86	.07	.070	.25	.70	.007	.41	.66	.011	1.15	.32	.029
Sex × Valence × Site	1.60	.21	.040	.35	.82	.009	1.87	.14	.047	2.34	.08	.058	.10	.96	.003

Appendix C Continued

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2
Condition × Valence × Site	1.31	.27	.033	2.15	.09	.054	1.95	.12	.049	2.68	.05	.066	.51	.70	.013
Sex × Condition × Valence × Site	.36	.60	.009	.42	.76	.011	.08	.98	.002	1.58	.20	.040	1.04	.38	.027

Appendix D: IAPS Normative Data and the Mean Valence and Arousal Ratings for Stimuli Presented in Study 2.

Appendix D

IAPS Normative Data and the Mean Valence and Arousal Ratings for Stimuli Presented in Study 2 for Early Follicular Women, Midluteal Women, and Men.

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
Neutral										
1333	6.42 (1.68)	5.79 (1.21)	5.43 (0.92)	5.90 (1.52)	5.22 (0.75)	2.96 (2.00)	3.38 (1.92)	2.39 (1.23)	2.76 (1.72)	2.48 (1.55)
2221	4.33 (1.24)	4.47 (1.20)	4.86 (0.71)	4.66 (1.11)	4.56 (0.80)	3.05 (1.83)	3.11 (2.40)	2.50 (1.32)	2.03 (1.84)	2.48 (1.34)
2312	3.51 (1.80)	4.00 (1.35)	4.96 (0.79)	4.38 (1.05)	4.63 (0.88)	4.20 (1.71)	3.77 (1.56)	2.18 (1.12)	2.93 (1.89)	2.26 (1.53)
2392	6.15 (1.50)	6.15 (1.49)	4.79 (.88)	5.21 (0.94)	5.48 (1.56)	3.79 (1.83)	2.90 (1.80)	1.93 (1.22)	2.45 (1.97)	2.56 (2.01)
2399	3.50 (1.56)	3.90 (1.15)	4.50 (0.96)	4.35 (1.23)	4.63 (0.74)	4.11 (2.07)	3.72 (1.93)	1.89 (1.07)	2.38 (1.82)	2.11 (1.34)
7078	3.52 (1.44)	4.31 (1.35)	4.25 (1.08)	4.10 (1.42)	4.59 (.89)	3.73 (1.78)	3.61 (2.02)	1.79 (1.07)	1.86 (1.41)	1.96 (1.05)
7079	3.77 (1.48)	3.86 (1.37)	4.54 (0.84)	4.21 (1.35)	4.59 (0.64)	4.38 (1.80)	4.61 (2.04)	1.93 (0.94)	2.93 (2.52)	2.19 (1.49)
9010	4.17 (1.78)	3.68 (1.57)	4.39 (.88)	4.07 (1.39)	4.59 (0.64)	3.98 (2.18)	4.32 (1.89)	2.07 (1.25)	2.41 (1.74)	1.96 (1.43)
9110	3.75 (1.44)	3.78 (1.41)	4.54 (0.96)	3.76 (1.53)	4.52 (0.94)	4.04 (2.29)	3.90 (2.18)	1.93 (1.02)	2.76 (2.15)	2.11 (1.09)
9390	3.32 (1.42)	4.04 (1.67)	4.46 (1.10)	4.38 (1.18)	4.59 (0.69)	4.68 (2.53)	3.54 (2.41)	1.93 (1.12)	2.41 (1.48)	2.00 (1.24)
9913	3.95 (1.95)	4.85 (1.72)	4.64 (.068)	4.83 (1.07)	5.07 (0.47)	4.40 (2.22)	4.45 (2.06)	2.21 (1.37)	2.72 (1.53)	2.33 (1.62)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
Neutral *(cont)*										
2525	3.89 (1.66)	4.29 (4.29)	4.54 (1.07)	4.41 (1.43)	4.89 (.58)	4.35 (2.03)	3.35 (2.23)	1.93 (0.98)	2.24 (1.60)	2.11 (1.48)
2515	6.31 (1.56)	5.70 (1.44)	5.18 (0.77)	5.48 (1.18)	5.19 (0.68)	3.91 (6.58)	3.62 (2.08)	1.93 (1.14)	2.93 (2.21)	2.26 (1.68)
5410	6.41 (1.63)	5.78 (1.46)	5.14 (0.76)	5.59 (1.12)	5.52 (1.89)	3.18 (2.29)	3.42 (1.86)	2.07 (1.15)	2.90 (2.26)	2.67 (2.08)
5720	6.58 (1.51)	6.02 (1.65)	5.36 (1.19)	5.59 (1.50)	5.19 (0.83)	2.78 (2.27)	2.80 (2.15)	1.93 (0.98)	2.66 (1.84)	2.15 (1.70)
5726	6.28 (1.60)	6.15 (1.61)	5.39 (.88)	5.55 (1.57)	5.19 (.92)	2.66 (1.85)	3.10 (2.26)	2.54 (1.31)	3.14 (1.90)	2.67 (1.44)
5875	6.16 (1.61)	5.85 (1.12)	5.29 (0.98)	5.79 (1.05)	5.11 (0.80)	3.24 (2.22)	3.36 (1.99)	2.21 (0.99)	2.93 (1.71)	2.48 (1.60)
7509	6.29 (1.48)	5.65 (1.06)	5.14 (0.59)	5.72 (1.22)	5.26 (0.90)	3.60 (2.15)	3.19 (1.83)	2.43 (1.29)	2.86 (2.25)	2.56 (1.67)
8251	5.84 (1.50)	6.49 (1.58)	5.21 (0.69)	5.45 (1.12)	5.41 (0.93)	4.62 (2.37)	6.20 (2.26)	2.39 (1.40)	3.31 (2.29)	2.89 (2.30)
8260	5.47 (1.72)	6.90 (1.60)	5.14 (0.59)	5.03 (1.09)	5.59 (1.19)	5.02 (1.93)	6.69 (2.11)	2.36 (1.70)	3.17 (2.25)	2.96 (2.30)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
Low AR PL										
1441	8.14 (1.33)	7.71 (1.17)	8.21 (0.83)	7.83 (1.00)	7.48 (1.19)	4.00 (2.55)	3.84 (2.10)	3.14 (1.38)	4.48 (2.15)	2.74 (1.98)
1610	8.00 (1.20)	7.32 (1.42)	8.04 (0.84)	7.48 (1.33)	7.11 (0.93)	3.75 (2.54)	4.24 (2.23)	3.39 (1.59)	4.24 (2.29)	2.26 (1.63)
2360	8.20 (1.59)	6.09 (1.76)	8.11 (0.83)	7.31 (1.07)	7.30 (1.14)	3.67 (2.52)	3.65 (2.02)	3.46 (1.40)	4.38 (1.84)	2.82 (1.90)
2370	7.43 (1.49)	6.71 (1.32)	8.00 (1.33)	7.31 (1.14)	7.07 (1.30)	2.93 (2.20)	2.85 (2.07)	3.29 (1.46)	4.17 (1.97)	2.48 (1.45)
2388	8.10 (1.15)	6.73 (1.40)	8.04 (0.69)	7.28 (1.25)	7.22 (1.15)	3.73 (2.46)	3.81 (1.92)	3.29 (1.15)	4.28 (1.91)	2.70 (1.61)
2530	8.25 (1.10)	7.25 (1.84)	8.04 (0.10)	7.55 (1.12)	7.19 (1.33)	3.80 (2.17)	4.23 (2.03)	2.79 (1.23)	3.97 (2.04)	2.82 (2.11)
5000	7.79 (1.63)	6.58 (1.77)	7.82 (1.89)	6.83 (1.17)	6.70 (1.38)	2.90 (1.92)	2.44 (2.06)	3.07 (1.46)	3.34 (1.82)	2.22 (1.67)
5001	7.78 (1.33)	6.40 (1.47)	8.14 (1.11)	7.10 (1.29)	7.19 (1.11)	3.94 (2.47)	3.64 (2.16)	3.29 (1.15)	3.52 (1.62)	2.78 (1.91)
5010	7.55 (1.39)	6.75 (1.52)	7.71 (1.08)	6.90 (1.18)	7.22 (1.28)	3.24 (2.43)	2.78 (2.07)	2.86 (1.27)	3.28 (1.64)	2.22 (1.80)
5200	7.69 (1.37)	6.96 (1.62)	8.00 (0.90)	6.86 (1.36)	7.11 (1.28)	2.98 (2.22)	3.46 (2.06)	3.11 (1.34)	3.35 (1.59)	2.67 (1.66)
5201	7.59 (1.50)	6.41 (1.72)	8.07 (0.77)	7.00 (1.41)	7.48 (1.09)	3.77 (2.71)	3.90 (2.24)	3.50 (1.23)	3.48 (1.48)	2.93 (1.64)
5202	7.74 (1.24)	6.44 (1.40)	8.46 (0.69)	7.55 (1.09)	7.26 (1.23)	3.87 (2.28)	3.50 (2.12)	3.32 (1.52)	4.03 (1.78)	2.33 (1.92)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
Low AR PL *(cont)*										
5551	7.79 (1.62)	6.79 (1.49)	7.79 (1.29)	6.97 (1.27)	7.11 (1.31)	3.23 (2.84)	3.28 (2.01)	2.86 (1.33)	3.69 (2.12)	2.48 (2.01)
5760	8.41 (1.07)	7.69 (1.28)	8.11 (0.92)	6.97 (1.02)	7.04 (1.34)	3.67 (2.56)	2.77 (2.16)	3.21 (1.42)	4.07 (1.79)	2.56 (1.50)
5779	7.72 (1.41)	6.69 (1.21)	8.25 (1.00)	7.55 (0.99)	7.26 (1.23)	3.54 (2.43)	3.62 (2.11)	3.04 (1.26)	4.14 (1.88)	2.82 (2.00)
5780	7.68 (1.44)	7.35 (1.46)	8.11 (0.63)	7.00 (1.13)	7.07 (1.24)	4.30 (2.47)	4.13 (2.60)	3.18 (1.56)	4.07 (1.75)	2.93 (1.88)
5781	7.28 (1.48)	6.90 (1.49)	8.11 (1.03)	6.79 (1.18)	7.30 (1.32)	3.69 (2.45)	4.02 (2.25)	3.00 (1.05)	4.00 (1.96)	2.85 (1.87)
5811	7.88 (1.24)	6.52 (1.65)	7.93 0(.90)	7.52 (1.15)	7.30 (1.44)	3.12 (2.66)	3.49 (1.92)	3.14 (1.41)	3.76 (1.85)	2.48 (1.50)
5891	7.58 (1.54)	6.83 (1.27)	7.61 (0.99)	6.93 (1.33)	7.30 (1.07)	3.14 (2.60)	3.46 (2.55)	2.89 (0.99)	3.21 (1.70)	2.44 (1.85)
7325	7.48 (1.66)	6.48 (1.47)	8.25 (1.08)	7.31 (1.31)	7.41 (.97)	3.77 (2.07)	3.24 (2.06)	3.18 (1.42)	4.31 (2.04)	2.41 (1.78)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
High AR PL										
2347	8.35 (0.98)	6.89 (1.45)	8.14 (0.76)	7.72 (1.07)	7.48 (1.09)	5.88 (2.53)	4.97 (1.84)	6.79 (2.11)	6.38 (1.99)	6.59 (1.58)
5470	7.33 (1.44)	7.38 (1.82)	7.93 (1.25)	6.69 (1.07)	7.44 (1.53)	5.61 (2.05)	6.44 (2.40)	7.36 (1.83)	6.03 (2.28)	7.11 (1.42)
5621	7.80 (1.54)	7.28 (1.22)	7.75 (1.24)	6.52 (1.43)	7.63 (1.24)	7.00 (2.13)	6.96 (1.72)	6.82 (2.07)	6.24 (1.96)	7.15 (0.99)
5629	7.15 (1.51)	6.89 (1.59)	7.64 (1.34)	6.86 (1.60)	7.63 (1.15)	6.52 (2.04)	6.59 (2.20)	6.96 (2.01)	6.14 (2.12)	6.70 (1.23)
5833	8.27 (0.99)	8.15 (1.19)	8.32 (0.77)	7.45 (1.24)	7.67 (1.07)	5.14 (2.79)	6.37 (2.37)	6.86 (1.35)	6.76 (1.75)	6.78 (1.67)
5910	8.16 (1.15)	7.41 (1.20)	8.11 (.88)	7.35 (1.04)	7.56 (1.40)	5.80 (2.75)	5.37 (2.32)	6.93 (1.92)	6.72 (1.31)	6.85 (1.32)
7405	7.55 (1.76)	7.08 (1.65)	8.21 (0.69)	7.62 (1.15)	7.56 (1.48)	6.41 (2.32)	6.03 (1.84)	7.25 (1.96)	6.28 (2.31)	6.82 (1.67)
8030	7.35 (1.86)	7.29 (1.66)	7.68 (1.31)	6.55 (1.43)	7.33 (1.24)	7.38 (1.91)	7.32 (2.16)	7.00 (1.78)	5.86 (2.07)	7.33 (1.14)
8034	7.19 (1.63)	6.90 (1.41)	7.86 (1.30)	6.69 (1.23)	7.22 (1.37)	6.38 (2.10)	6.20 (2.24)	6.89 (2.02)	5.79 (1.99)	6.78 (1.45)
8080	7.73 (1.43)	7.73 (1.25)	7.89 (1.55)	6.59 (1.50)	7.33 (1.33)	6.25 (2.34)	7.12 (1.95)	6.79 (2.22)	5.69 (2.33)	6.63 (1.21)
8163	7.38 (1.50)	6.69 (1.73)	7.93 (1.25)	6.76 (1.18)	7.48 (1.58)	6.53 (2.39)	6.54 (1.85)	6.89 (2.02)	5.55 (2.56)	6.93 (0.99)
8170	7.59 (1.24)	7.67 (1.44)	7.79 (1.55)	6.76 (1.50)	7.26 (1.53)	5.67 (2.55)	6.57 (1.94)	6.54 (2.20)	5.66 (2.60)	6.70 (1.90)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
High AR PL *(cont)*										
8185	7.75 (1.46)	7.32 (1.58)	7.75 (1.21)	6.79 (1.37)	7.59 (1.19)	7.42 (2.07)	7.06 (2.09)	6.64 (2.04)	6.72 (2.05)	6.85 (1.13)
8186	6.83 (1.70)	7.22 (1.38)	7.61 (1.59)	6.21 (2.00)	7.44 (1.22)	6.72 (1.99)	6.98 (2.05)	7.11 (2.15)	6.14 (2.10)	6.93 (1.17)
8190	8.08 (1.48)	8.13 (1.29)	7.96 (1.26)	7.00 (1.31)	7.59 (1.08)	6.16 (2.57)	6.41 (2.60)	6.79 (1.95)	6.24 (2.10)	7.15 (1.38)
8200	7.86 (1.12)	7.15 (1.54)	7.79 (1.47)	6.45 (1.12)	7.15 (1.43)	6.37 (1.94)	6.33 (2.05)	6.93 (2.11)	6.03 (2.21)	6.89 (1.34)
8370	7.86 (1.37)	7.67 (1.19)	7.75 (1.27)	6.83 (1.26)	7.41 (1.37)	6.98 (2.25)	6.46 (2.22)	7.11 (2.02)	6.48 (1.90)	7.11 (1.55)
8490	7.44 (2.33)	6.85 (2.36)	8.00 (1.39)	6.83 (1.14)	7.41 (1.47)	6.97 (1.94)	6.25 (1.96)	7.11 (1.91)	6.35 (2.21)	7.30 (0.95)
8492	7.11 (2.49)	7.36 (1.87)	9.07 (1.46)	6.76 (1.50)	7.82 (1.21)	7.48 (1.51)	7.07 (1.80)	6.89 (2.01)	6.55 (2.32)	7.04 (1.37)
8501	7.67 (1.97)	8.14 (1.24)	8.04 (1.53)	6.83 (1.39)	7.26 (1.48)	6.02 (2.50)	6.86 (2.00)	7.07 (1.96)	6.07 (2.53)	7.11 (1.65)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
Low AR UNPL										
2205	1.65 (1.05)	2.24 (1.93)	2.07 (1.22)	2.21 (1.61)	2.59 (1.05)	4.65 (2.04)	4.41 (2.42)	4.04 (1.35)	5.62 (2.29)	2.48 (1.53)
2375.1	1.91 (1.19)	2.55 (1.37)	1.96 (1.04)	1.83 (1.10)	3.04 (0.90)	5.22 (2.16)	4.48 (2.21)	3.79 (1.23)	5.00 (2.43)	2.63 (1.33)
2750	2.55 (1.19)	2.57 (1.46)	1.96 (0.96)	1.90 (1.08)	2.89 (0.93)	4.55 (1.66)	4.06 (1.93)	4.00 (1.31)	5.28 (2.33)	2.78 (0.93)
2900.1	2.14 (1.30)	3.26 (1.33)	2.04 (1.14)	2.24 (1.35)	3.04 (1.37)	4.90 (2.04)	4.12 (2.06)	4.25 (1.27)	5.24 (2.13)	2.82 (1.30)
3300	2.35 (1.30)	3.14 (1.72)	2.11 (1.07)	2.03 (1.23)	2.93 (1.07)	4.96 (1.98)	4.14 (2.07)	4.07 (1.18)	5.24 (2.23)	3.00 (1.18)
6311	2.36 (1.72)	2.82 (1.33)	2.04 (1.17)	1.24 (1.32)	2.93 (1.04)	5.12 (2.51)	4.77 (1.98)	4.04 (1.23)	4.55 (2.59)	2.82 (1.47)
9000	2.33 (1.45)	2.81 (1.65)	2.11 (1.20)	2.59 (2.06)	2.67 (1.36)	4.19 (2.37)	3.90 (2.12)	4.25 (1.32)	5.14 (2.31)	2.93 (1.57)
9220	1.86 (1.46)	2.27 (1.61)	1.82 (0.90)	2.17 (1.39)	2.96 (1.40)	4.16 (1.84)	3.83 (2.33)	4.25 (1.29)	4.93 (2.28)	2.70 (1.14)
9280	2.69 (1.47)	2.96 (1.63)	2.21 (1.37)	2.31 (1.63)	2.74 (1.38)	4.05 (2.35)	4.55 (2.54)	4.04 (1.20)	5.07 (2.58)	2.78 (1.01)
9290	2.76 (1.44)	3.06 (1.63)	1.93 (1.02)	2.03 (1.35)	2.93 (1.11)	4.44 (2.01)	4.33 (2.27)	3.75 (1.40)	4.83 (2.71)	2.44 (1.19)
9291	2.72 (1.21)	3.29 (1.05)	1.96 (1.07)	1.97 (1.27)	2.93 (0.78)	4.90 (1.81)	3.52 (2.14)	3.89 (1.23)	4.59 (2.37)	2.30 (.78)
9320	2.26 (1.82)	3.07 (1.96)	1.79 (0.96)	1.28 (0.65)	2.52 (0.94)	5.32 (2.82)	4.50 (2.52)	4.14 (1.65)	5.41 (2.85)	2.37 (1.36)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
Low AR UNPL *(cont)*										
9330	2.78 (1.73)	3.00 (1.76)	1.86 (0.97)	2.00 (1.28)	3.07 (0.96)	4.44 (2.10)	4.26 (2.05)	4.00 (1.41)	4.52 (2.56)	2.52 (0.85)
9331	2.67 (1.27)	3.09 (1.27)	2.07 (1.27)	2.72 (1.75)	3.15 (1.17)	4.25 (2.20)	3.42 (1.67)	3.93 (1.18)	4.66 (2.39)	2.33 (1.14)
9342	2.53 (1.30)	3.22 (1.45)	1.82 (0.90)	2.07 (1.39)	3.15 (1.13)	4.56 (1.86)	4.40 (1.90)	4.14 (1.15)	4.83 (2.42)	2.70 (1.07)
9415	2.58 (2.14)	3.06 (1.83)	1.75 (0.80)	2.31 (1.49)	2.93 (0.99)	5.32 (2.37)	4.50 (2.29)	4.36 (1.22)	5.14 (2.36)	2.70 (1.14)
9432	1.95 (1.32)	3.29 (1.74)	2.07 (1.18)	2.52 (1.82)	2.74 (0.94)	5.58 (2.20)	4.12 (2.13)	4.25 (1.38)	5.17 (2.33)	3.00 (1.41)
9830	2.42 (1.88)	2.65 (1.63)	1.82 (0.94)	1.90 (1.21)	3.11 (1.01)	4.92 (2.57)	4.80 (2.72)	3.82 (1.39)	4.76 (2.59)	2.56 (1.25)
9831	2.83 (1.72)	3.14 (1.72)	1.82 (1.02)	2.14 (1.51)	2.96 (1.43)	4.91 (2.46)	4.20 (2.06)	3.68 (1.28)	4.28 (2.45)	2.41 (1.25)
9832	2.68 (1.56)	3.31 (1.55)	2.07 (1.05)	1.86 (1.36)	2.89 (1.12)	4.86 (2.01)	3.90 (2.01)	3.75 (1.35)	4.31 (2.66)	2.56 (1.05)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
High AR UNPL										
3000	1.21 (0.80)	1.69 (1.47)	1.64 (1.06)	1.24 0(.58)	2.26 0(.90)	7.77 (1.66)	6.74 (2.37)	7.14 (2.05)	6.62 (3.08)	6.56 (2.31)
3001	1.33 (0.80)	2.10 (1.43)	1.82 (1.25)	1.14 (0.44)	2.22 (0.93)	7.10 (2.43)	5.85 (2.56)	7.04 (2.10)	6.38 (3.29)	6.85 (2.33)
3010	1.47 (1.04)	2.19 (1.42)	1.61 (1.23)	1.10 (0.41)	2.30 (0.91)	7.38 (1.96)	7.12 (1.75)	7.18 (2.02)	6.52 (3.30)	6.48 (2.23)
3053	1.15 (0.73)	1.50 (1.16)	1.57 (1.07)	1.10 (0.31)	2.30 (0.95)	7.51 (2.29)	6.20 (2.71)	7.04 (2.08)	5.52 (3.21)	6.70 (1.92)
3060	1.66 (1.71)	1.94 (1.39)	1.50 (1.04)	1.07 (0.26)	2.48 (1.12)	7.34 (2.10)	6.89 (2.08)	7.04 (2.12)	6.62 (3.42)	6.78 (1.95)
3063	1.18 (0.65)	1.84 (1.12)	1.57 (2.20)	1.10 (0.41)	2.48 (1.12)	7.18 (2.12)	5.44 (2.78)	7.04 (1.93)	6.55 (3.28)	7.07 (2.02)
3064	1.15 (.44)	1.78 (1.26)	1.68 (1.57)	1.10 (0.41)	2.48 (1.56)	7.30 (2.22)	5.44 (2.70)	7.00 (2.19)	6.38 (3.39)	6.37 (2.11)
3068	1.18 (0.70)	2.47 (1.92)	1.61 (1.17)	1.10 (0.41)	2.07 (0.96)	7.09 (2.49)	6.44 (2.46)	7.04 (2.13)	6.55 (3.44)	6.74 (1.99)
3069	1.32 (1.01)	2.10 (1.66)	1.54 (1.04)	1.10 (0.31)	2.04 (0.85)	7.33 (2.20)	6.70 (2.60)	6.86 (1.98)	6.55 (3.32)	7.19 (2.13)
3071	1.69 (1.14)	2.06 (1.59)	1.71 (1.05)	1.31 (0.60)	2.37 (0.88)	7.10 (1.95)	6.61 (2.13)	7.04 (1.88)	6.52 (3.17)	7.19 (2.22)
3080	1.33 (0.75)	1.63 (1.11)	1.50 (1.17)	1.10 (0.41)	2.37 (1.01)	7.61 (1.81)	6.84 (2.06)	6.86 (2.22)	6.28 (3.40)	6.89 (1.95)
3102	1.22 (0.85)	1.62 (1.39)	1.61 (0.99)	1.07 (0.26)	2.52 (0.89)	7.15 (2.48)	5.88 (2.79)	7.07 (2.02)	6.66 (3.42)	6.22 (2.03)

Appendix D Continued

IAPS #	Mean Valence					Mean Arousal				
	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
High AR UNPL *(cont)*										
3110	1.47 (0.89)	2.10 (1.56)	1.61 (1.17)	1.28 (0.65)	2.19 (0.92)	6.98 (2.04)	6.43 (2.26)	6.89 (2.17)	6.17 (3.26)	6.41 (2.04)
3140	1.50 (0.97)	2.22 (1.27)	1.71 (1.21)	1.21 (0.49)	2.41 (0.93)	6.94 (1.68)	5.68 (2.08)	7.04 (1.97)	6.38 (3.37)	6.59 (2.12)
3170	1.20 (0.57)	1.77 (1.31)	1.79 (1.23)	1.24 (0.64)	2.30 (0.91)	7.55 (1.98)	6.79 (1.93)	7.14 (1.96)	6.24 (3.27)	6.59 (2.04)
3266	1.26 (0.56)	1.98 (1.28)	1.68 (1.89)	1.21 (0.49)	2.37 (0.97)	7.43 (1.74)	5.85 (2.21)	7.04 (2.13)	6.62 (3.30)	6.89 (1.85)
3400	2.06 (1.77)	2.67 (2.01)	1.57 (1.17)	1.07 (0.26)	2.33 (0.73)	7.12 (2.14)	6.67 (2.29)	7.18 (2.00)	6.38 (3.34)	6.74 (1.68)
9183	1.48 (0.81)	2.00 (1.38)	1.61 (1.17)	1.48 (1.38)	2.37 (0.88)	6.92 (2.04)	6.07 (2.16)	6.75 (2.01)	6.07 (3.41)	6.26 (2.16)
9252	1.53 (1.25)	2.51 (1.78)	1.43 (1.17)	1.10 (0.31)	2.37 (1.01)	6.93 (2.33)	6.27 (2.30)	7.21 (2.08)	6.62 (3.06)	6.85 (1.81)
9405	1.59 (1.02)	2.09 (1.27)	1.50 (1.00)	1.07 (0.26)	2.41 (0.97)	6.77 (2.22)	5.31 (2.38)	7.14 (2.03)	6.41 (3.41)	6.70 (2.18)

Note. Standard Deviations in parentheses; IAPS = International Affective Picture System; EF = Early Follicular Women; ML = Midluteal Women.

Appendix E: Study 2 Analyses.

Appendix E

Means and Standard Deviations for Stimuli Conditions in Study 2 for Early Follicular Women, Midluteal Women, and Men for Relevant ERP Component Sites.

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
P1		O1	OZ	OZ	O1	OZ	O2	O1	OZ	O2
	PL/Low AR	6.51 (6.19)	3.99 (5.88)	5.65 (6.64)	8.73 (7.21)	5.71 (6.76)	7.53 (6.76)	3.88 (4.47)	2.99 (3.74)	3.72 (3.85)
	PL/High AR	6.91 (6.08)	4.75 (6.64)	5.98 (6.52)	9.49 (7.42)	5.82 (5.98)	8.08 (5.63)	3.67 (3.31)	2.85 (3.00)	3.20 (3.61)
	Neutral	7.60 (5.89)	4.98 (5.93)	6.93 (6.13)	9.56 (8.38)	6.05 (6.82)	7.99 (6.30)	5.17 (4.23)	4.15 (4.14)	4.54 (4.25)
	UNPL/Low AR	6.16 (5.67)	4.08 (5.82)	5.72 (6.38)	8.88 (7.48)	5.90 (6.06)	7.83 (5.82)	4.47 (4.85)	3.34 (3.58)	3.96 (4.39)
	UNPL/High AR	5.62 (5.71)	3.57 (6.69)	5.21 (6.17)	8.63 (7.02)	5.50 (6.19)	8.18 (6.02)	3.96 (3.44)	3.06 (2.95)	3.45 (3.57)
N1		F3	FZ	F4	F3	FZ	F4	F3	FZ	F4
	PL/Low AR	-6.13 (2.29)	-7.13 (2.99)	-6.54 (3.02)	-7.10 (3.39)	-7.48 (3.87)	-6.84 (3.44)	-5.19 (3.22)	-5.65 (3.81)	-5.31 (3.55)
	PL/High AR	-7.14 (3.07)	-7.67 (3.41)	-6.93 (3.05)	-7.47 (3.87)	-7.95 (4.45)	-7.06 (3.49)	-5.23 (3.15)	-5.69 (3.63)	-5.18 (3.10)
	Neutral	-6.96 (3.26)	-7.53 (3.48)	-6.86 (3.22)	-6.85 (3.01)	-7.35 (3.10)	-7.10 (3.04)	-5.10 (2.76)	-5.19 (3.07)	-4.91 (2.92)
	UNPL/Low AR	-6.58 (3.18)	-7.35 (3.42)	-6.70 (3.13)	-7.55 (2.75)	-8.14 (2.54)	-7.78 (2.44)	-5.86 (2.99)	-5.63 (3.35)	-5.22 (3.47)
	UNPL/High AR	-6.55 (3.24)	-7.11 (3.36)	-6.30 (3.30)	-7.35 (2.72)	-8.06 (2.93)	-7.53 (2.75)	-5.33 (3.54)	-5.70 (3.65)	-5.48 (3.65)

Appendix E Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
N2		F3	FZ	F4	F3	FZ	F4	F3	FZ	F4
	PL/Low AR	-7.61 (5.13)	-8.17 (5.23)	-7.27 (4.56)	-8.42 (3.81)	-9.21 (4.41)	-8.46 (4.47)	-7.05 (4.05)	-7.90 (4.16)	-7.38 (4.24)
	PL/High AR	-7.86 (4.79)	-8.94 (5.37)	-8.11 (4.94)	-9.20 (3.80)	-10.20 (4.26)	-9.46 (4.00)	-7.91 (4.59)	-8.82 (4.61)	-8.25 (4.20)
	Neutral	-9.37 (4.73)	-10.07 (5.37)	-9.21 (4.79)	-8.89 (4.22)	-9.79 (4.76)	-9.30 (4.64)	-9.00 (4.72)	-9.94 (5.02)	-9.58 (4.79)
	UNPL/Low AR	-9.94 (5.23)	-10.79 (5.14)	-9.68 (4.60)	-9.84 (4.43)	-10.59 (5.03)	-9.97 (5.07)	-8.81 (4.37)	-9.96 (4.70)	-9.36 (4.55)
	UNPL/High AR	-6.75 (5.70)	-8.04 (6.26)	-6.81 (5.71)	-7.51 (5.22)	-8.56 (6.00)	-7.49 (5.74)	-5.47 (4.76)	-6.32 (5.10)	-5.78 (4.71)
P3		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	PL/Low AR	5.32 (4.03)	3.69 (4.89)	6.55 (4.94)	5.61 (4.87)	4.97 (5.67)	7.11 (5.39)	7.23 (4.88)	6.18 (4.73)	8.53 (4.53)
	PL/High AR	6.70 (3.92)	5.78 (5.20)	8.19 (5.07)	7.26 (5.53)	6.35 (6.65)	8.08 (5.96)	8.02 (4.07)	6.96 (4.12)	8.95 (4.90)
	Neutral	7.06 (3.73)	6.23 (5.03)	8.78 (4.50)	6.97 (5.60)	6.22 (6.45)	7.72 (5.94)	7.75 (3.76)	7.05 (4.44)	8.20 (4.25)
	UNPL/Low AR	7.32 (3.77)	6.31 (4.92)	9.07 (4.33)	7.82 (5.24)	6.97 (6.37)	8.83 (5.86)	9.21 (4.07)	8.12 (4.12)	9.53 (3.93)
	UNPL/High AR	12.20 (4.81)	12.59 (6.20)	13.49 (5.54)	12.22 (7.11)	13.51 (7.88)	14.02 (7.23)	12.11 (4.98)	12.16 (5.33)	12.44 (5.31)

Appendix E Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
LPP		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	PL/Low AR	2.55 (3.09)	3.11 (4.02)	2.98 (3.38)	3.42 (3.82)	3.53 (3.80)	4.11 (3.76)	2.56 (2.58)	2.08 (3.14)	2.66 (2.80)
	PL/High AR	3.73 (3.18)	3.66 (3.78)	3.62 (3.71)	3.97 (3.85)	3.61 (3.51)	4.27 (3.52)	2.80 (2.40)	2.43 (3.08)	2.99 (2.95)
	Neutral	3.97 (2.99)	3.89 (3.55)	4.09 (3.31)	2.99 (3.44)	2.86 (3.91)	3.64 (4.07)	3.03 (2.29)	2.69 (3.11)	2.90 (2.74)
	UNPL/Low AR	4.72 (3.44)	4.60 (4.23)	4.83 (3.65)	4.53 (3.98)	4.21 (4.43)	4.85 (4.29)	4.07 (2.79)	3.15 (3.66)	3.12 (3.03)
	UNPL/High AR	9.29 (4.70)	10.62 (5.28)	9.38 (4.97)	9.22 (6.72)	10.15 (6.64)	9.40 (5.70)	7.13 (3.43)	7.51 (4.37)	6.48 (3.88)

Note. Standard Deviations in parentheses; PL = pleasant, UNPL = unpleasant; AR = arousing.

Appendix E

Repeated Measure ANOVA Results for Study 2 Experimental Variables and Variable Interactions for Early Follicular Women, Midluteal Women, and Men for each ERP Component.

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	3.95	.02	.089	4.17	.02	.093	.41	.66	.010	.27	.77	.007	1.39	.26	.033
Condition	3.01	.03	.036	.78	.52	.010	19.13	<.001	.191	16.94	<.001	.569	12.92	<.001	.601
Site	27.66	<.001	.255	22.38	<.001	.216	34.87	<.001	.301	22.82	<.001	.220	.20	.81	.002
Group × Condition	.71	.65	.017	.62	.74	.015	1.09	.37	.026	1.85	.08	.044	2.03	.06	.048
Group × Site	2.73	.04	.063	1.25	.30	.030	.97	.42	.023	.72	.58	.017	1.51	.21	.036
Condition × Site	.87	.52	.011	.89	.51	.011	1.43	.20	.017	12.41	<.001	.133	14.77	<.001	.15
Group × Condition × Site	.88	.57	.02	1.51	.11	.036	.76	.66	.019	1.47	.13	.035	1.09	.36	.026

Appendix E

Correlations between Anxiety (DASS) and ERP Component during Condition across All Groups

ERP Component	Condition	*r*	*p*
P1			
	PL/Low AR	.002	.99
	PL/High AR	.054	.62
	Neutral	.058	.60
	UNPL/Low AR	.049	.66
	UNPL/High AR	.066	.55
N1			
	PL/Low AR	-.194	.08
	PL/High AR	-.259	.02*
	Neutral	-.147	.18
	UNPL/Low AR	-.206	.06
	UNPL/High AR	-.119	.28
N2			
	PL/Low AR	.035	.75
	PL/High AR	-.106	.34
	Neutral	-.104	.90
	UNPL/Low AR	-.009	.93
	UNPL/High AR	-.068	.54

Appendix E Continued

ERP Component	Condition	*r*	*p*
<u>P3</u>			
	PL/Low AR	-.293	.007**
	PL/High AR	-.296	.006**
	Neutral	-.185	.09
	UNPL/Low AR	-.199	.07
	UNPL/High AR	-.195	.08
<u>LPP</u>			
	PL/Low AR	-.113	.30
	PL/High AR	-.105	.34
	Neutral	-.115	.30
	UNPL/Low AR	-.117	.29
	UNPL/High AR	-.106	.34

Note: N=84 for all analyses; PL = pleasant, UNPL = unpleasant; AR = arousing. Prior to Bonferroni correction: ** = <.01; * = p<.05; No significant correlations following Bonferroni correction were found.

Appendix E

Correlations between Progesterone and ERP Component during Condition across All Groups

Variable	*r*	*p*
P1		
PL/Low AR	.134	.22
PL/High AR	.223	.04*
Neutral	.185	.09
UNPL/Low AR	.243	.03*
UNPL/High AR	.298	**.006****
N1		
PL/Low AR	-.330	**.002****
PL/High AR	-.348	**.001****
Neutral	-.218	.05*
UNPL/Low AR	-.270	**.01***
UNPL/High AR	-.228	.04*

Note: N=84 for all analyses; Progesterone was correlated with ERP amplitudes where we observed ‘Group’ differences signalling a direct role of progesterone upon the obtained ‘Group’ findings. Prior to Bonferroni correction: ** = $p<.01$, * = $p<.05$; Bolded font = correlation significant following Bonferroni correction.

Appendix F: Study 2 Analyses (Excluding Contraceptive Use).

Appendix F

Means and Standard Deviations for Stimuli Conditions in Study 2 for Early Follicular Women, Midluteal Women, and Men for Relevant ERP Component Sites (Excluding Contraceptive Use).

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
P1		O1	OZ	OZ	O1	OZ	O2	O1	OZ	O2
	PL/Low AR	6.71 (6.45)	4.03 (6.13)	5.60 (6.90)	8.72 (7.21)	5.71 (6.76)	7.53 (6.76)	3.88 (4.47)	2.99 (3.74)	3.72 (3.85)
	PL/High AR	6.97 (6.30)	4.88 (6.75)	5.99 (6.73)	9.49 (7.42)	5.82 (5.98)	8.08 (5.63)	3.67 (3.31)	2.85 (3.00)	3.20 (3.61)
	Neutral	7.28 (5.93)	4.79 (5.89)	6.72 (6.35)	9.56 (8.38)	6.05 (6.82)	7.99 (6.30)	5.17 (4.23)	4.15 (4.14)	4.54 (4.25)
	UNPL/Low AR	6.47 (5.69)	4.27 (5.78)	5.90 (6.36)	8.88 (7.48)	5.90 (6.06)	7.83 (5.82)	4.47 (4.85)	3.33 (3.58)	3.96 (4.39)
	UNPL/High AR	5.72 (5.96)	3.71 (6.95)	5.43 (6.38)	8.63 (7.02)	5.50 (6.18)	8.18 (6.02)	3.96 (3.44)	3.06 (2.95)	3.45 (3.57)
N1		F3	FZ	F4	F3	FZ	F4	F3	FZ	F4
	PL/Low AR	-6.01 (2.38)	-7.09 (3.14)	-6.60 (3.17)	-7.10 (3.39)	-7.48 (3.87)	-6.84 (3.44)	-5.19 (3.22)	-5.65 (3.81)	-5.31 (3.55)
	PL/High AR	-7.03 (2.80)	-7.57 (3.19)	-6.91 (3.04)	-7.47 (3.87)	-7.95 (4.45)	-7.06 (3.49)	-5.23 (3.15)	-5.69 (3.63)	-5.18 (3.09)
	Neutral	-6.51 (3.39)	-7.13 (3.55)	-6.24 (3.50)	-7.35 (2.72)	-8.06 (2.93)	-7.53 (2.75)	-5.33 (3.54)	-5.70 (3.65)	-5.48 (3.65)
	UNPL/Low AR	-6.65 (3.20)	-7.27 (3.49)	-6.66 (3.31)	-6.85 (3.01)	-7.35 (3.10)	-7.10 (3.04)	-5.10 (2.76)	-5.19 (3.07)	-4.91 (2.92)
	UNPL/High AR	-6.30 (3.13)	-7.08 (3.41)	-6.52 (3.24)	-7.55 (2.75)	-8.14 (2.54)	-7.78 (2.44)	-5.86 (2.99)	-5.63 (3.34)	-5.21 (3.47)

Appendix F Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
N2		F3	FZ	F4	F3	FZ	F4	F3	FZ	F4
	PL/Low AR	-7.05 (4.25)	-7.62 (4.35)	-7.03 (4.24)	-8.42 (3.81)	-9.21 (4.41)	-8.46 (4.47)	-7.05 (4.05)	-7.90 (4.16)	-7.38 (4.24)
	PL/High AR	-7.67 (4.26)	-8.72 (5.00)	-8.09 (4.92)	-9.20 (3.80)	-10.20 (4.26)	-9.46 (4.00)	-7.91 (4.59)	-8.82 (4.61)	-8.25 (4.20)
	Neutral	-9.33 (4.23)	-10.01 (4.82)	-9.24 (4.53)	-8.89 (4.22)	-9.79 (4.76)	-9.30 (4.64)	-9.00 (4.72)	-9.94 (5.02)	-9.58 (4.79)
	UNPL/Low AR	-9.73 (4.71)	-10.50 (4.71)	-9.51 (4.57)	-9.84 (4.43)	-10.59 (5.03)	-9.97 (5.07)	-8.81 (4.37)	-9.96 (4.70)	-9.36 (4.55)
	UNPL/High AR	-6.79 (5.63)	-9.09 (6.30)	-7.04 (5.89)	-7.51 (5.22)	-8.56 (6.00)	-7.49 (5.74)	-5.47 (4.76)	-6.32 (5.10)	-5.78 (4.71)
P3		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	PL/Low AR	5.50 (4.22)	3.74 (5.16)	6.66 (5.21)	5.61 (4.87)	4.97 (5.67)	7.11 (5.39)	7.23 (4.88)	6.18 (4.73)	8.53 (4.53)
	PL/High AR	6.75 (4.15)	5.74 (5.39)	8.24 (5.24)	7.26 (5.53)	6.35 (6.65)	8.08 (5.96)	8.02 (4.07)	6.96 (4.11)	8.94 (4.90)
	Neutral	7.02 (3.88)	6.16 (5.16)	8.84 (4.64)	6.97 (5.60)	6.22 (6.44)	7.72 (5.93)	7.75 (3.77)	7.05 (4.44)	8.30 (4.24)
	UNPL/Low AR	7.49 (3.59)	6.36 (5.17)	9.38 (4.47)	7.82 (5.24)	6.97 (6.37)	8.83 (5.86)	9.21 (4.07)	8.12 (4.12)	9.53 (3.93)
	UNPL/High AR	12.18 (4.97)	12.44 (6.43)	13.62 (5.80)	12.22 (7.11)	13.51 (7.88)	14.02 (7.23)	12.11 (4.98)	12.16 (5.33)	12.44 (5.31)

Appendix F Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
LPP		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	PL/Low AR	2.49 (3.22)	3.01 (4.19)	2.99 (3.39)	3.42 (3.83)	3.53 (3.80)	4.11 (3.76)	2.56 (2.58)	2.08 (3.14)	2.66 (2.80)
	PL/High AR	3.70 (3.28)	3.56 (3.86)	3.62 (3.71)	3.97 (3.85)	3.61 (3.51)	4.27 (3.53)	2.80 (2.40)	2.43 (3.08)	2.99 (2.95)
	Neutral	3.82 (2.93)	3.72 (3.53)	4.00 (3.32)	2.99 (3.44)	2.86 (3.91)	3.64 (4.07)	3.03 (2.29)	2.69 (3.11)	2.90 (2.74)
	UNPL/Low AR	4.78 (3.64)	4.58 (4.47)	4.97 (3.73)	4.53 (3.98)	4.20 (4.43)	4.84 (4.29)	4.07 (2.79)	3.15 (3.66)	3.12 (3.03)
	UNPL/High AR	9.26 (4.85)	10.53 (5.52)	9.36 (5.08)	9.26 (4.85)	10.15 (6.64)	9.40 (5.70)	7.13 (3.43)	7.51 (4.37)	6.48 (3.88)

Note. Standard Deviations in parentheses; PL = pleasant, UNPL = unpleasant; AR = arousing.

Appendix F

Repeated Measure ANOVA Results for Study 2 Experimental Variables and Variable Interactions for Early Follicular Women, Midluteal Women, and Men for each ERP Component (Excluding Contraceptive Use).

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	3.84	.03	.090	3.97	.02	.092	.46	.63	.012	.22	.80	.06	1.30	.28	.03
Condition	2.46	.05	.031	.75	.55	.009	17.96	<.001	.19	102.83	<.001	.569	17.09	<.001	.600
Site	26.28	<.001	.252	20.09	<.001	.221	37.68	<.001	.326	23.49	<.001	.231	.32	.71	.004
Group × Condition	.60	.75	.015	.52	.92	.013	1.26	.27	.031	1.70	.11	.042	1.95	.07	.048
Group × Site	2.68	.04	.064	1.33	.26	.033	.52	.69	.013	.90	.47	.022	1.28	.28	.032
Condition × Site	.88	.51	.011	.92	.48	.012	1.26	.28	.016	11.55	<.001	.129	14.45	<.001	.156
Group × Condition × Site	.99	.45	.025	1.61	.09	.040	.95	.50	.024	1.55	.10	.038	1/08	.37	.027

Appendix G: Study 3 Analyses (Early Follicular and Midluteal Women Collapsed).

Appendix G

Means and Standard Deviations for Stimuli Conditions in Study 2 for Men and Early Follicular and Midluteal Women Collapsed for Relevant ERP Component Sites.

Component (and Sites)	Condition	Early Follicular and Midluteal Women Collapsed			Men		
P1		O1	OZ	OZ	O1	OZ	O2
	PL/Low AR	7.64 (6.76)	4.87 (6.35)	6.61 (6.71)	3.88 (4.47)	2.99 (3.74)	3.72 (3.85)
	PL/High AR	8.23 (6.86)	5.30 (6.28)	7.05 (6.12)	3.67 (3.31)	2.85 (3.00)	3.20 (3.61)
	Neutral	8.59 (7.27)	5.52 (6.36)	7.47 (6.18)	5.17 (4.23)	4.15 (4.14)	4.54 (4.25)
	UNPL/Low AR	7.54 (6.73)	5.01 (5.96)	6.79 (6.14)	4.47 (4.85)	3.33 (3.58)	3.96 (4.39)
	UNPL/High AR	7.15 (6.53)	4.55 (6.46)	6.72 (6.22)	3.96 (3.44)	3.06 (2.95)	3.45 (3.57)
N1		F3	FZ	F4	F3	FZ	F4
	PL/Low AR	-.59 (2.31)	-.63 (2.64)	-.31 (2.39)	-.03 (1.38)	.40 (1.55)	.33 (1.61)
	PL/High AR	-.63 (2.21)	-.52 (2.27)	-.26 (2.14)	.47 (1.45)	.42 (1.62)	.59 (1.51)
	Neutral	-.30 (2.31)	-.42 (2.71)	-.09 (2.48)	-.42 (2.42)	-.31 (2.42)	-.2.3 (2.44)
	UNPL/Low AR	-.74 (2.01)	-.73 (2.08)	-.56 (1.90)	.07 (1.26)	-.16 (1.55)	-.14 (1.45)
	UNPL/High AR	-.63 (2.36)	-.65 (1.97)	-.44 (1.85)	.16 (1.81)	.15 (2.22)	.17 (1.78)

Appendix G Continued

Component (and Sites)	Condition	Early Follicular and Midluteal Women Collapsed			Men		
N2		F3	FZ	F4	F3	FZ	F4
	PL/Low AR	-8.02 (4.48)	-8.70 (4.82)	-7.87 (4.51)	-7.05 (4.05)	-7.90 (4.16)	-7.38 (4.24)
	PL/High AR	-8.54 (4.33)	-9.58 (4.84)	-8.80 (4.50)	-7.91 (4.59)	-8.82 (4.61)	-8.25 (4.20)
	Neutral	-9.13 (4.45)	-9.93 (5.02)	-9.26 (4.67)	-9.00 (4.72)	-9.94 (5.02)	-9.58 (4.79)
	UNPL/Low AR	-9.89 (4.79)	-10.69 (5.04)	-9.83 (4.80)	-8.81 (4.37)	-9.96 (4.70)	-9.36 (4.55)
	UNPL/High AR	-7.14 (5.43)	-8.30 (6.08)	-7.16 (5.68)	-5.47 (4.76)	-6.32 (5.10)	-5.78 (4.71)
P3		P3	PZ	P4	P3	PZ	P4
	PL/Low AR	1.64 (5.26)	-1.13 (5.20)	2.86 (4.95)	3.31 (4.41)	.96 (4.53)	4.44 (4.28)
	PL/High AR	1.49 (5.58)	-1.71 (5.15)	2.53 (5.19)	3.08 (3.90)	.98 (4.65)	4.06 (4.26)
	Neutral	1.15 (4.30)	-2.21 (5.02)	2.12 (4.90)	2.96 (4.34)	.12 (5.46)	3.33 (4.61)
	UNPL/Low AR	1.35 (5.30)	-1.82 (5.84)	2.40 (5.32)	3.76 (3.57)	.80 (3.99)	4.08 (4.67)
	UNPL/High AR	3.06 (5.75)	.15 (6.14)	3.96 (5.40)	4.40 (3.74)	2.04 (4.41)	5.06 (4.40)

Appendix G Continued

Component (and Sites)	Condition	Early Follicular and Midluteal Women Collapsed			Men		
LPP		P3	PZ	P4	P3	PZ	P4
	PL/Low AR	2.99 (3.48)	3.33 (3.88)	3.56 (3.59)	2.56 (2.58)	2.08 (3.14)	2.66 (2.80)
	PL/High AR	3.85 (3.51)	3.63 (3.61)	3.95 (3.60)	2.80 (2.40)	2.43 (3.08)	2.99 (2.95)
	Neutral	3.47 (3.24)	3.37 (3.74)	3.86 (3.69)	3.03 (2.29)	2.69 (3.11)	2.90 (2.74)
	UNPL/Low AR	4.62 (3.70)	4.40 (4.30)	4.84 (3.95)	4.07 (2.79)	3.15 (3.66)	3.12 (3.03)
	UNPL/High AR	9.25 (5.76)	10.38 (5.96)	9.39 (5.31)	7.13 (3.43)	7.51 (4.37)	6.48 (3.88)

Note. Standard Deviations in parentheses; PL = Pleasant, UNPL = Unpleasant; AR = Arousing.

Appendix G

Repeated Measure ANOVA Results for Study 2 Experimental Variable Main Effects and Interactions for Early Follicular and Midluteal Women Collapsed and Men for each ERP Component.

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	5.59	.02	.06	3.92	.05	.046	.59	.45	.007	3.83	.05	.045	2.82	.09	.033
Condition	2.82	.04	.033	.53	.70	.006	19.01	<.001	.188	5.11	.002	.059	95.08	<.001	.537
Site	17.84	<.001	.179	4.74	.01	.055	29.67	<.001	.266	63.96	<.001	.438	.15	.85	.002
Group × Condition	.78	.51	.009	.87	.48	.010	1.17	.32	.014	.22	.87	.003	2.75	.04	.032
Group × Site	4.54	.02	.052	1.68	.19	.020	1.43	.24	.017	.90	.41	.011	1.83	.17	.022
Condition × Site	.50	.81	.006	.83	.54	.010	.92	.49	.011	.96	.45	.012	13.24	<.001	.139
Group × Condition × Site	.81	.56	.010	.80	.56	.010	.86	.52	.010	.48	.82	.006	1.95	.07	.023

Appendix H: Study 3 Analyses (Replication of Lithari et al. (2010) Analyses).

Appendix H

Means and Standard Deviations for Replication of Lithari et al. (2010) Analysis for Early Follicular Women, Midluteal Women, and Men for Relevant ERP Component Sites.

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
P1		FZ	CZ	PZ	FZ	CZ	PZ	FZ	CZ	PZ
	PL/Low AR	-0.57 (2.17)	0.03 (2.92)	2.65 (5.53)	-0.68 (3.06)	-0.67 (3.86)	2.74 (5.58)	0.40 (2.38)	0.11 (2.30)	3.26 (4.41)
	PL/High AR	-0.40 (2.05)	0.14 (3.14)	2.23 (5.31)	-0.63 (2.50)	-0.36 (3.30)	3.17 (4.77)	0.42 (1.62)	0.76 (1.55)	3.30 (3.75)
	UNPL/Low AR	-0.89 (2.34)	-0.44 (2.87)	2.25 (4.70)	-0.58 (1.82)	-0.89 (2.91)	2.71 (4.85)	-0.16 (1.55)	-0.14 (1.55)	3.54 (3.14)
	UNPL/High AR	-0.50 (1.79)	0.09 (2.81)	2.11 (5.64)	-0.79 (2.16)	-1.16 (2.21)	2.23 (4.62)	0.14 (2.22)	0.60 (2.58)	3.71 (4.36)
N1		FZ	CZ	PZ	FZ	CZ	PZ	FZ	CZ	PZ
	PL/Low AR	-7.13 (2.99)	-6.44 (3.84)	-4.37 (5.38)	-7.48 (3.87)	-6.34 (5.14)	-2.81 (6.45)	-6.65 (3.81)	-4.24 (4.14)	-2.11 (3.51)
	PL/High AR	-7.67 (3.41)	-7.72 (4.03)	-5.41 (4.98)	-7.95 (4.45)	-6.86 (5.13)	-3.56 (5.31)	-5.69 (3.63)	-4.17 (3.74)	-2.14 (3.02)
	UNPL/Low AR	-7.52 (3.48)	-7.08 (3.81)	-5.18 (5.48)	-7.35 (3.10)	-6.87 (3.94)	-3.28 (5.94)	-5.19 (3.07)	-3.57 (2.32)	-1.79 (2.87)
	UNPL/High AR	-7.35 (3.42)	-7.17 (4.54)	-4.88 (6.10)	-8.14 (2.54)	-7.91 (3.96)	-4.52 (5.92)	-5.63 (3.35)	-3.38 (3.81)	-1.96 (3.25)

Appendix H Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
N2		FZ	CZ	PZ	FZ	CZ	PZ	FZ	CZ	PZ
	PL/Low AR	-8.17 (5.23)	-7.01 (4.75)	-2.54 (4.13)	-9.21 (4.41)	-8.05 (5.26)	0.21 (5.82)	-7.90 (4.16)	-5.51 (4.35)	0.96 (4.53)
	PL/High AR	-8.94 (5.37)	-7.91 (5.41)	-2.88 (4.64)	-10.20 (4.26)	-8.53 (5.27)	-0.59 (5.44)	-8.82 (4.61)	-5.92 (4.41)	0.98 (4.65)
	UNPL/Low AR	-10.79 (5.14)	-9.56 (5.39)	-3.32 (5.31)	-10.59 (5.03)	-9.26 (6.12)	-0.37 (6.05)	-9.96 (4.70)	-6.95 (4.16)	0.80 (3.99)
	UNPL/High AR	-8.04 (6.27)	-6.87 (6.57)	-1.71 (4.74)	-8.56 (6.01)	-6.53 (6.75)	1.94 (6.84)	-6.32 (5.10)	-3.75 (4.96)	2.04 (5.68)
P3		FZ	CZ	PZ	FZ	CZ	PZ	FZ	CZ	PZ
	PL/Low AR	-0.52 (4.52)	0.79 (5.40)	3.69 (4.89)	-0.80 (3.75)	0.07 (3.99)	4.97 (5.67)	0.41 (4.31)	2.16 (5.43)	6.18 (4.73)
	PL/High AR	0.03 (5.72)	2.03 (6.50)	5.78 (5.20)	-1.04 (3.44)	0.86 (4.83)	6.35 (6.65)	0.16 (3.24)	3.15 (4.54)	6.96 (4.11)
	UNPL/Low AR	0.15 (5.20)	2.36 (5.44)	6.31 (4.92)	-1.03 (4.23)	0.53 (4.98)	6.97 (6.37)	0.04 (4.40)	3.56 (4.52)	8.12 (4.12)
	UNPL/High AR	3.47 (5.84)	7.99 (6.40)	12.59 (6.20)	3.28 (5.74)	7.30 (6.84)	13.51 (7.87)	3.68 (6.90)	8.32 (6.82)	12.16 (5.33)

Appendix H Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
LPP		FZ	CZ	PZ	FZ	CZ	PZ	FZ	CZ	PZ
	PL/Low AR	0.39 (2.95)	2.65 (3.76)	3.11 (4.02)	-0.01 2.44)	2.68 (3.49)	3.53 (3.80)	1.12 (3.46)	3.20 (2.91)	2.08 (3.14)
	PL/High AR	1.96 (4.04)	3.81 (4.71)	3.66 (3.78)	0.89 (3.35)	3.64 (3.81)	3.61 (3.51)	1.06 (2.87)	3.89 (3.00)	2.43 (3.08)
	UNPL/Low AR	0.38 (3.52)	3.30 (4.22)	4.60 (4.23)	-0.34 (2.75)	2.55 (3.48)	4.21 (4.42)	0.82 (3.48)	3.84 (3.42)	3.15 (3.66)
	UNPL/High AR	4.19 (4.74)	9.11 (5.55)	10.62 (5.28)	3.47 (4.50)	8.48 (5.65)	10.15 (6.64)	3.37 (6.36)	8.52 (5.34)	7.51 (4.37)

Note. Standard Deviations in parentheses; PL = pleasant, UNPL = unpleasant; AR = arousing.

Appendix H

Repeated Measure ANOVA Results for Replication of Lithari et al. (2010) Analysis for Early Follicular Women, Midluteal Women, and Men for each ERP Component.

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	1.30	.28	.031	5.62	.005	.122	2.38	.09	.056	.61	.55	.015	.28	.76	.007
Valence	1.64	.20	.020	.13	.72	.002	.20	.65	.002	121.62	<.001	.600	88.03	<.001	.52
Arousal	.56	.46	.007	7.46	.008	.084	18.93	<.001	.189	129.68	<.001	.616	14.30	<.001	.640
Site	50.65	<.001	.385	35.13	<.001	.303	18.37	<.001	.696	108.84	<.001	.573	52.81	<.001	.40
Group × Valence	.17	.84	.004	1.15	.32	.028	1.22	.30	.029	.52	.60	.013	.38	.69	.009
Group × Arousal	.32	.73	.008	1.35	.27	.032	.24	.79	.006	1.34	.27	.032	1.96	.15	.046
Group × Site	.45	.66	.011	1.17	.32	.028	3.51	.02	.080	.97	.40	.023	2.05	.12	.048
Valence × Arousal	.009	.93	.000	.09	.76	.001	36.53	<.001	.31	65.12	<.001	.45	81.09	<.001	.500
Valence × Site	.28	.73	.003	.98	.37	.012	4.06	.03	.048	55.06	<.001	.405	60.47	<.001	.427
Arousal × Site	1.44	.24	.017	.42	.62	.005	3.32	.04	.039	30.48	<.001	.273	15.63	<.001	.16
Group × Valence × Arousal	.58	.56	.014	1.80	.17	.043	.004	.99	.000	.96	.39	.023	.44	.65	.011
Group × Valence × Site	1.07	.37	.026	1.35	.26	.032	.61	.60	.015	.71	.55	.017	1.21	.31	.029

Appendix H Continued

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group × Arousal × Site	.52	.72	.013	.69	.57	.017	1.50	.21	.036	2.27	.09	.053	.51	.67	.012
Valence × Arousal × Site	.26	.74	.003	.21	.77	.003	8.10	.001	.091	2.09	.14	.025	25.98	<.001	.243
Group × Valence × Arousal × Site	.21	.91	.005	.24	.88	.006	2.83	.04	.065	1.01	.40	.024	1.18	.32	.028

Appendix I: Reprint of Lusk, B. R., Carr, A., Ranson, V., Bryant, R. A., & Felmingham, K. (2015).

This article has been removed for copyright or proprietary reasons.

Lusk, B. R., Carr, A. R., Ranson, V. A., Bryant, R. A., Felmingham, K. L., 2015. Early visual processing is enhanced in the midluteal phase of themenstrual cycle, Psychoneuroendocrinology, 62, 343-351

Appendix J: IAPS Normative Data and the Mean Valence and Arousal Ratings for Stimuli Presented in Study 3.

Appendix J

IAPS Normative Data and the Mean Valence and Arousal Ratings for Stimuli Presented in Study 3 for Early Follicular Women, Midluteal Women, and Men

	Mean Valence					Mean Arousal				
IAPS Number	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
1033	3.25 (1.77)	4.93 (1.77)	2.36 (1.25)	2.41 (1.78)	3.07 (1.07)	6.29 (2.22)	5.86 (2.02)	5.18 (1.36)	7.28 (2.20)	2.37 (1.57)
1310	4.05 (1.49)	5.27 (1.54)	2.00 (0.82)	2.48 (1.86)	3.26 (1.02)	6.09 (1.96)	5.89 (1.61)	5.61 (1.34)	7.35 (1.91)	2.37 (1.64)
1321	3.90 (1.86)	4.94 (1.71)	2.21 (1.33)	2.41 (1.78)	3.22 (1.15)	6.85 (1.85)	6.34 (1.94)	5.32 (1.36)	7.21 (2.45)	2.63 (1.57)
1525	2.67 (1.74)	3.55 (1.59)	2.61 (0.99)	2.24 (1.48)	3.22 (0.75)	6.86 (2.16)	6.14 (2.31)	5.32 (1.44)	7.55 (1.97)	2.51 (1.63)
1820	4.99 (2.14)	5.85 (1.83)	2.25 (1.00)	2.66 (1.96)	3.44 (0.75)	5.91 (2.04)	5.33 (2.13)	5.32 (1.38)	7.72 (2.07)	2.52 (1.45)
1931	3.57 (2.13)	4.51 (2.35)	2.29 (0.90)	2.41 (1.80)	3.04 (1.09)	6.73 (2.23)	6.88 (1.77)	5.43 (1.50)	7.83 (1.93)	2.33 (1.49)
1932	2.92 (1.87)	4.85 (1.89)	2.25 (0.89)	2.38 (1.50)	2.93 (0.99)	6.73 (2.2.0)	6.21 (2.18)	5.43 (1.35)	7.83 (2.12)	2.70 (1.46)
1050	3.02 (1.93)	3.90 (2.28)	2.50 (1.20)	2.35 (1.74)	3.04 (1.02)	6.90 (1.82)	6.84 (1.55)	5.39 (1.75)	7.10 (2.18)	2.48 (1.63)
1120	3.03 (1.74)	4.73 (1.75)	2.21 (0.83)	2.28 (1.77)	3.30 (0.91)	7.20 (1.86)	6.60 (1.38)	5.43 (1.79)	7.31 (1.95)	2.37 (1.33)
1202	2.98 (1.65)	4.04 (1.81)	2.29 (0.76)	2.00 (1.58)	3.07 (0.83)	5.80 (2.47)	6.20 (1.45)	5.36 (1.54)	7.38 (2.01)	2.74 (1.87)

Appendix J Continued

	Mean Valence					Mean Arousal				
IAPS Number	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
1205	3.22 (1.62)	4.15 (1.78)	2.11 (0.96)	2.17 (1.67)	3.07 (0.83)	5.94 (2.22)	5.61 (2.13)	5.00 (1.44)	7.79 (1.76)	2.63 (2.00)
1300	3.41 (1.63)	4.06 (1.54)	1.96 (0.84)	2.24 (1.43)	3.22 (0.70)	6.70 (2.04)	6.90 (1.59)	5.57 (1.75)	7.62 (1.93)	2.70 (2.07)
1301	3.32 (1.53)	4.10 (1.71)	2.32 (1.09)	2.45 (1.72)	3.41 (0.75)	5.91 (1.96)	5.63 (2.39)	5.25 (1.38)	7.41 (2.28)	2.63 (1.50)
1303	4.66 (2.22)	4.72 (1.94)	2.43 (1.03)	2.48 (1.81)	3.22 (1.01)	5.96 (1.79)	5.24 (2.35)	5.46 (1.45)	7.59 (2.01)	2.63 (1.50)
1304	3.02 (1.47)	3.89 (1.60)	2.36 (0.95)	2.17 (1.63)	2.96 (0.98)	6.35 (1.96)	6.39 (1.90)	5.57 (1.57)	7.28 (2.05)	2.48 (1.74)
6415	1.65 (1.15)	2.81 (1.63)	1.71 (0.53)	1.24 (0.69)	2.70 (0.82)	6.51 (2.32)	5.86 (2.27)	6.29 (1.54)	8.23 (0.94)	2.37 (2.13)
9185	1.70 (1.06)	2.36 (1.19)	1.96 (0.74)	1.52 (0.78)	3.00 (0.68)	6.41 (2.05)	4.60 (2.35)	5.75 (1.53)	7.72 (1.31)	2.42 (1.25)
9186	3.03 (1.49)	4.02 (1.44)	2.00 (0.82)	1.97 (1.24)	3.15 (0.60)	5.14 (1.88)	4.50 (1.82)	5.71 (1.51)	7.55 (1.80)	2.11 (1.12)
9560	2.18 (1.99)	2.07 (1.89)	2.32 (1.06)	1.93 (1.31)	3.15 (0.60)	5.54 (2.47)	5.46 (2.60)	5.61 (1.77)	7.59 (1.70)	2.52 (1.40)
9561	2.21 (1.66)	3.20 (2.07)	2.00 (0.61)	1.35 (0.77)	2.89 (0.93)	5.35 (2.26)	4.18 (2.19)	6.11 (1.71)	7.93 (1.22)	2.63 (1.45)
9570	1.47 (1.00)	1.90 (1.40)	1.89 (0.68)	1.28 (0.45)	2.56 (0.89)	6.45 (2.19)	5.84 (2.41)	6.14 (1.74)	7.97 (1.45)	2.15 (1.59)
9571	1.38 (1.09)	2.65 (1.62)	1.79 (0.50)	1.41 (0.63)	2.59 (0.97)	6.46 (2.34)	4.68 (2.35)	5.64 (1.54)	7.93 (1.56)	2.00 (1.24)

Appendix J Continued

IAPS Number	Mean Valence IAPS Women	IAPS Men	EF	ML	Men	Mean Arousal IAPS Women	IAPS Men	EF	ML	Men
9140	1.88 (1.26)	2.56 (1.42)	1.89 (0.83)	2.00 (1.28)	3.00 (0.78)	5.79 (2.04)	4.90 (2.29)	5.43 (1.50)	7.79 (1.72)	2.00 (1.00)
9145	2.91 (1.29)	3.67 (1.43)	2.18 (0.90)	1.90 (1.23)	3.19 (0.48)	5.25 (2.14)	4.71 (2.43)	5.71 (1.56)	8.03 (1.68)	2.48 (1.60)
9150	4.42 (1.75)	4.73 (1.92)	2.39 (0.99)	1.93 (1.56)	3.11 (0.70)	5.43 (1.98)	5.10 (2.35)	5.25 (1.67)	7.79 (1.93)	2.37 (1.71)
9171	3.41 (1.73)	4.66 (1.95)	2.21 (1.13)	2.51 (1.81)	3.56 (1.19)	4.69 (2.24)	4.75 (2.11)	5.32 (1.56)	7.48 (1.70)	2.11 (1.22)
9180	3.19 (1.78)	2.76 (1.36)	2.14 (0.97)	1.62 (1.01)	3.15 (0.72)	4.98 (1.95)	5.07 (2.26)	5.39 (1.34)	7.55 (1.74)	2.19 (1.08)
9181	1.98 (1.98)	2.54 (1.69)	1.61 (0.73)	1.69 (0.85)	3.11 (0.75)	6.09 (2.19)	4.67 (2.42)	5.61 (1.20)	7.93 (1.44)	2.63 (1.18)
9182	3.64 (2.28)	3.39 (1.76)	1.79 (0.92)	1.62 (0.90)	2.78 (0.81)	5.35 (2.24)	4.53 (1.77)	5.68 (1.28)	7.86 (1.27)	2.52 (1.55)
9183	1.48 (0.81)	2.00 (1.38)	1.75 (0.75)	1.41 (0.95)	2.74 (0.98)	6.92 (2.04)	6.07 (2.16)	5.57 (1.40)	7.76 (1.43)	2.33 (1.52)
3530	1.51 (1.00)	2.10 (1.53)	1.86 (0.59)	1.62 (0.86)	2.82 (0.92)	6.80 (2.07)	6.85 (2.13)	5.61 (1.69)	7.97 (1.18)	2.37 (1.52)
9075	1.29 (0.64)	2.29 (1.40)	2.04 (0.43)	1.48 (0.78)	3.19 (0.74)	6.57 (2.39)	5.15 (2.16)	6.00 (1.61)	8.12 (1.39)	2.41 (1.62)
9413	1.43 (0.70)	2.23 (1.32)	1.86 (0.71)	1.38 (0.62)	3.11 (0.80)	7.35 (1.71)	6.06 (2.35)	5.89 (1.57)	8.38 (1.32)	2.00 (1.21)
9611	2.42 (1.92)	3.02 (1.95)	2.11 (0.88)	2.00 (1.39)	3.22 (0.70)	6.00 (2.37)	5.50 (2.50)	5.57 (1.50)	7.72 (1.73)	2.30 (1.75)

Appendix J Continued

	Mean Valence					Mean Arousal				
IAPS Number	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
9901	2.07 (1.15)	2.59 (1.34)	2.07 (0.94)	1.83 (1.26)	3.00 (0.92)	5.89 (2.21)	5.41 (2.22)	5.32 (1.33)	7.52 (1.94)	2.26 (1.48)
9911	1.88 (1.16)	2.81 (1.42)	2.00 (0.82)	1.93 (1.31)	3.04 (0.98)	6.28 (2.06)	5.15 (1.99)	5.54 (1.45)	7.62 (1.99)	2.44 (1.22)
9940	1.47 (1.13)	1.91 (1.29)	1.68 (0.55)	1.66 (1.14)	2.89 (0.85)	7.03 (2.35)	7.37 (2.03)	5.82 (1.66)	8.31 (1.04)	2.63 (2.19)
6021	1.88 (1.18)	2.75 (1.81)	1.61 (0.57)	1.38 (0.73)	2.89 (0.93)	6.32 (2.37)	5.65 (2.36)	5.71 (1.56)	7.93 (1.67)	2.26 (1.46)
6212	1.81 (1.41)	2.59 (1.47)	1.64 (0.56)	1.52 (0.95)	3.07 (0.78)	6.53 (2.35)	5.47 (2.44)	5.79 (1.69)	8.48 (1.09)	2.63 (1.78)
6260	2.35 (1.45)	2.53 (1.63)	2.04 (0.84)	1.86 (1.33)	3.15 (0.91)	6.76 (1.97)	7.10 (1.90)	5.86 (1.51)	8.07 (1.89)	2.37 (1.67)
6312	2.08 (1.47)	2.88 (1.48)	2.18 (0.72)	1.76 (1.21)	3.19 (0.83)	6.83 (2.19)	5.90 (2.35)	5.50 (1.23)	7.83 (1.97)	2.33 (1.14)
6350	1.44 (0.95)	2.39 (1.42)	1.61 (0.83)	1.66 (1.01)	3.26 (0.81)	7.52 (1.99)	7.04 (1.73)	5.68 (1.44)	7.55 (1.86)	2.37 (1.47)
6520	1.59 (1.01)	2.45 (1.43)	1.89 (0.50)	1.52 (0.78)	3.11 (0.70)	7.12 (1.72)	5.85 (2.32)	5.68 (1.54)	8.17 (1.17)	2.48 (1.45)
6550	2.08 (1.90)	3.39 (2.63)	1.96 (0.69)	1.59 (0.91)	2.67 (0.83)	7.20 (1.83)	6.98 (2.13)	5.96 (1.43)	7.93 (1.49)	2.22 (1.45)
6831	2.21 (1.52)	2.98 (1.39)	2.04 (0.96)	1.90 (1.23)	2.67 (0.83)	6.09 (2.05)	5.00 (2.15)	5.79 (1.45)	7.66 (2.04)	2.33 (1.59)
3000	1.21 (0.80)	1.69 (1.47)	1.71 (0.53)	1.10 (0.31)	2.74 (1.06)	7.77 (1.66)	6.74 (2.37)	5.93 (1.56)	7.93 (1.33)	2.52 (1.95)

Appendix J Continued

	Mean Valence					Mean Arousal				
IAPS Number	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
3261	1.70 (1.43)	1.98 (1.19)	1.46 (0.58)	1.14 (0.35)	3.00 (0.78)	5.92 (2.60)	5.51 (2.70)	5.75 (1.65)	8.10 (0.77)	2.22 (1.63)
3350	1.76 (1.72)	2.00 (1.62)	1.89 (0.83)	1.83 (1.31)	2.85 (0.72)	5/78 (2.21)	5.65 (2.27)	5.54 (1.40)	7.97 (1.24)	2.37 (1.39)
9042	2.44 (1.50)	3.93 (1.98)	1.86 (0.52)	1.48 (0.87)	2.89 (0.93)	6.38 (2.43)	5.13 (2.39)	5.46 (1.73)	8.31 (0.85)	2.30 (1.32)
9410	1.20 (0.58)	1.96 (1.56)	1.82 (0.48)	1.31 (0.47)	2.82 (1.00)	7.54 (1.78)	6.38 (2.26)	5.75 (1.76)	8.24 (1.24)	2.37 (1.64)
9420	1.87 (1.54)	2.96 (1.44)	1.79 (0.42)	1.38 (0.56)	2.70 (0.95)	6.10 (2.37)	5.10 (2.02)	5.21 (1.57)	8.14 (1.36)	2.19 (1.55)
9433	1.35 (0.71)	2.39 (1.38)	1.54 (0.73)	1.48 (0.74)	2.48 (0.80)	6.71 (2.27)	5.00 (2.65)	5.43 (1.73)	7.97 (1.43)	2.52 (1.65)
3001	1.33 (0.80)	2.10 (1.43)	1.25 (0.52)	1.17 (0.47)	2.85 (0.95)	7.10 (2.43)	5.85 (2.56)	6.18 (1.85)	8.17 (1.26)	2.22 (1.65)
3010	1.47 (1.05)	2.19 (1.42)	1.57 (0.50)	1.21 (0.41)	2.89 (0.89)	7.38 (1.96)	7.12 (1.75)	5.86 (1.84)	8.24 (1.15)	2.59 (1.78)
3015	1.34 (0.71)	1.83 (1.19)	1.61 (0.50)	1.10 (0.31)	2.85 (0.82)	6.11 (2.87)	5.54 (2.74)	5.96 (1.79)	8.52 (0.91)	2.41 (1.78)
3051	2.06 (1.96)	2.56 (1.74)	1.68 (0.55)	1.24 (0.51)	2.70 (0.87)	6.00 (2.40)	5.23 (2.46)	5.93 (1.63)	8.17 (1.39)	2.00 (1.57)
3064	1.15 (0.44)	1.78 (1.26)	2.04 (0.84)	1.21 (0.41)	2.33 (0.68)	7.30 (2.22)	5.44 (2.70)	6.14 (1.76)	8.28 (0.99)	2.19 (1.80)
3069	1.32 (1.01)	2.10 (1.66)	1.75 (0.44)	1.10 (0.31)	2.48 (0.75)	7.33 (2.20)	6.70 (2.60)	5.89 (1.75)	8.35 (1.14)	2.19 (1.96)

Appendix J Continued

	Mean Valence					Mean Arousal				
IAPS Number	IAPS Women	IAPS Men	EF	ML	Men	IAPS Women	IAPS Men	EF	ML	Men
3195	1.79 (1.06)	2.56 (1.38)	2.14 (0.76)	1.62 (0.94)	2.48 (0.94)	6.42 (2.53)	6.23 (1.63)	5.61 (1.61)	8.03 (1.50)	2.44 (1.89)
3213	2.61 (2.03)	3.63 (1.57)	1.89 (0.63)	1.66 (1.23)	2.82 (0.92)	6.79 (2.22)	6.89 (1.55)	5.64 (1.54)	8.21 (1.24)	2.37 (1.90)

Note. Standard Deviations in parentheses; IAPS = International Affective Picture System; EF = Early Follicular Women; ML = Midluteal Women.

Appendix K: Study 3 Analyses.

Appendix K

Means and Standard Deviations for Stimuli Conditions in Study 3 for Early Follicular Women, Midluteal Women, and Men at Relevant ERP Component Sites.

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
P1		O1	OZ	O2	O1	OZ	O2	O1	OZ	O2
	Reappraise	6.97 (4.99)	4.77 (5.06)	6.82 (5.52)	8.81 (6.91)	6.10 (5.27)	6.68 (5.46)	4.69 (4.25)	4.23 (4.14)	4.92 (4.94)
	Maintain (Reappraise)	-0.18 (1.87)	-0.13 (1.50)	0.19 (1.80)	0.69 (2.22)	0.46 (1.79)	0.54 (1.69)	-0.08 (1.92)	0.27 (1.33)	0.09 (1.66)
	Suppression	7.79 (5.90)	5.67 (5.36)	6.91 (5.51)	7.55 (5.20)	5.11 (4.62)	6.81 (4.91)	5.30 (4.83)	5.05 (5.42)	5.48 (5.16)
	Maintain (Suppression)	-0.28 (2.39)	0.20 (1.47)	0.05 (1.93)	-0.29 (2.22)	-0.09 (1.56)	0.09 (1.82)	-0.04 (1.81)	-0.03 (1.40)	0.16 (1.61)
N1		FC3	FCZ	FC4	FC3	FCZ	FC4	FC3	FCZ	FC4
	Reappraise	-6.35 (2.78)	-7.24 (3.02)	-6.06 (2.47)	-7.43 (3.72)	-9.06 (4.55)	-7.56 (3.75)	-5.54 (3.14)	-6.29 (4.30)	-5.32 (3.50)
	Maintain (Reappraise)	-6.61 (3.01)	-7.54 (3.51)	-6.45 (2.99)	-6.97 (3.52)	-8.17 (4.53)	-7.25 (2.99)	-5.02 (2.79)	-5.59 (3.66)	-5.18 (4.05)
	Suppression	-6.76 (3.29)	-7.53 (3.65)	-6.49 (3.55)	-7.84 (4.02)	-9.59 (4.91)	-8.20 (4.13)	-5.58 (4.27)	-5.73 (4.23)	-4.87 (3.52)
	Maintain (Suppression)	-6.02 (3.18)	-6.77 (3.63)	-5.95 (3.33)	-7.08 (3.25)	-8.27 (4.10)	-6.85 (3.22)	-6.08 (4.90)	-6.33 (5.59)	-5.99 (4.48)

Appendix K Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
N2		FC3	FCZ	FC4	FC3	FCZ	FC4	FC3	FCZ	FC4
	Reappraise	-3.99 (5.98)	-5.23 (6.28)	-3.91 (5.18)	-6.57 (5.20)	-8.25 (6.23)	-6.13 (5.22)	-5.61 (5.82)	-6.67 (6.26)	-5.43 (5.03)
	Maintain (Reappraise)	-4.16 (5.95)	-5.19 (6.67)	-3.33 (5.14)	-7.08 (5.59)	-8.69 (6.71)	-6.79 (5.57)	-4.68 (5.37)	-5.30 (5.90)	-4.69 (4.79)
	Suppression	-7.21 (5.09)	-9.02 (6.16)	-6.88 (4.76)	-9.03 (5.14)	-11.54 (6.35)	-8.72 (5.72)	-5.56 (5.70)	-6.65 (7.41)	-5.21 (5.99)
	Maintain (Suppression)	-5.42 (5.30)	-6.45 (6.06)	-5.00 (5.37)	-7.32 (4.83)	-9.35 (6.54)	-7.42 (5.87)	-5.41 (5.60)	-6.51 (5.93)	-4.99 (4.67)
P3		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	Reappraise	10.45 (4.28)	11.22 (5.61)	11.88 (4.51)	10.99 (6.71)	11.54 (4.77)	11.97 (6.81)	11.96 (5.20)	11.93 (4.77)	12.96 (6.14)
	Maintain (Reappraise)	10.57 (4.52)	11.09 (6.49)	12.46 (4.43)	10.24 (6.28)	11.28 (1.23)	11.92 (5.70)	10.17 (4.05)	9.91 (4.62)	11.22 (4.90)
	Suppression	8.53 (3.49)	8.21 (4.77)	9.97 (3.86)	9.57 (6.66)	9.53 (7.90)	10.15 (6.81)	10.44 (3.99)	10.24 (4.32)	11.08 (5.23)
	Maintain (Suppression)	8.96 (4.17)	9.04 (6.00)	10.79 (4.61)	10.09 (6.74)	11.17 (8.31)	11.89 (6.57)	10.12 (4.40)	10.99 (5.15)	11.25 (5.31)

Appendix K Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
LPP		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	Reappraise	6.63 (4.65)	7.95 (5.29)	6.94 (5.15)	5.51 (4.62)	6.03 (5.95)	5.81 (4.69)	5.70 (4.50)	5.75 (4.93)	5.65 (5.05)
	Maintain (Reappraise)	6.48 (4.08)	7.31 (5.45)	6.70 (3.89)	5.10 (4.80)	5.60 (5.64)	5.72 (4.02)	4.77 (2.79)	4.55 (3.03)	4.89 (3.21)
	Suppression	5.40 (3.55)	5.77 (4.14)	5.24 (3.80)	5.45 (5.47)	5.99 (6.40)	5.59 (5.79)	5.29 (3.29)	5.33 (3.80)	4.87 (4.02)
	Maintain (Suppression)	5.56 (3.55)	6.08 (4.71)	5.83 (3.98)	5.43 (5.89)	6.03 (6.65)	6.01 (5.91)	5.23 (2.77)	5.51 (3.21)	4.74 (3.17)

Note. Standard Deviations in parentheses.

Appendix K

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Maintain (Reappraisal) and Maintain (Suppression) for Early Follicular Women, Midluteal Women, and Men for each ERP Component.

Variable		P1			N1			N2			P3			LPP	
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	0.31	.73	.008	1.94	.15	.046	2.56	.08	.059	.12	.89	.003	.83	.44	.020
Condition	1.09	.30	.013	.032	.86	<.001	4.20	.04	.049	1.44	.23	.017	.05	.82	.001
Site	2.25	.11	.027	18.61	<.001	.187	34.50	<.001	.30	10.63	<.001	.116	1.99	.14	.024
Group × Condition	.97	.38	.023	1.66	.20	.039	.38	.69	.009	2.33	.10	.054	1.78	.18	.042
Group × Site	.40	.79	.010	1.50	.21	.036	1.51	.20	.036	.56	.69	.014	.83	.51	.020
Condition × Site	.40	.64	.005	.60	.55	.007	.86	.42	.010	.32	.69	.004	.79	.44	.010
Group × Condition × Site	1.06	.37	.026	.64	.63	.016	1.54	.20	.037	1.23	.30	.029	1.69	.16	.040

Appendix K

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Reappraisal and Maintain (Reappraisal) for Early Follicular Women, Midluteal Women, and Men for each ERP Component.

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2
Group	3.21	.046	.073	3.73	.03	.084	2.18	.12	.051	.01	1.0	<.001	1.41	.25	.034
Condition	9.54	<.001	.55	.57	.45	.007	.36	.55	.004	3.10	.08	.037	2.23	.14	.027
Site	13.47	<.001	.14	27.73	<.001	.255	33.27	<.001	.291	8.12	.001	.091	2.83	.06	.034
Group × Condition	1.48	.23	.035	.83	.44	.020	1.64	.20	.039	2.52	.09	.058	.34	.71	.008
Group × Site	3.23	.02	.074	1.23	.299	.030	1.45	.224	.035	.45	.77	.011	1.56	.19	.037
Condition × Site	17.18	<.001	.18	2.86	.06	.034	.65	.49	.008	.89	.40	.011	1.51	.23	.018
Group × Condition × Site	1.33	.26	.032	.57	.68	.014	1.70	.16	.040	.33	.82	.008	.23	.90	.006

Appendix K

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Suppression and Maintain (Suppression) for Early Follicular Women, Midluteal Women, and Men for each ERP Component.

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2
Group	.63	.53	.015	2.83	.07	.065	2.53	.09	.059	.61	.55	.015	.15	.86	.004
Condition	13.29	<.001	.583	1.03	.31	.013	17.54	<.001	.18	4.39	.04	.051	.29	.59	.004
Site	9.80	<.001	.108	19.98	<.001	.198	53.23	<.001	.397	9.10	<.001	.101	2.55	.08	.031
Group × Condition	.68	.51	.016	2.51	.09	.058	3.35	.040	.076	.83	.44	.020	.11	.89	.003
Group × Site	1.63	.17	.039	2.55	.05	.059	1.72	.15	.041	.82	.51	.020	.68	.61	.016
Condition × Site	11.65	<.001	.126	.81	.45	.010	2.65	.075	.032	7.73	.001	.087	1.01	.36	.012
Group × Condition × Site	2.10	.09	.049	1.81	.13	.043	1.03	.39	.025	1.00	.41	.024	.75	.55	.018

Appendix L: Study 3 Analyses (Excluding Contraceptive Use).

Appendix L

Means and Standard Deviations for Stimuli Conditions in Study 3 for Early Follicular Women, Midluteal Women, and Men at Relevant ERP Component Sites (Excluding Contraceptive Use).

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
P1		O1	OZ	O2	O1	OZ	O2	O1	OZ	O2
	Reappraise	6.50 (4.77)	4.57 (5.15)	6.67 (5.80)	8.81 (6.91)	6.10 (5.27)	7.68 (5.46)	4.69 (4.24)	4.23 (4.14)	4.92 (4.94)
	Maintain (Reappraise)	-0.07 (1.92)	-0.09 (1.57)	0.26 (1.80)	0.69 (2.22)	0.46 (1.79)	0.54 (1.69)	-0.08 (1.92)	0.27 (1.33)	0.09 (1.66)
	Suppression	7.50 (6.06)	5.45 (5.40)	6.63 (5.70)	7.55 (5.20)	5.11 (4.62)	6.81 (4.90)	5.30 (4.83)	5.05 (5.42)	5.48 (5.16)
	Maintain (Suppression)	-0.35 (2.43)	0.25 (1.52)	-0.02 (2.00)	-0.29 (2.22)	-0.09 (1.56)	-0.02 (1.82)	-0.04 (1.81)	-0.03 (1.41)	0.16 (1.61)
N1		FC3	FCZ	FC4	FC3	FCZ	FC4	FC3	FCZ	FC4
	Reappraise	-6.24 (2.85)	-7.14 (3.15)	-5.86 (2.49)	-7.43 (3.72)	-9.06 (4.55)	-7.56 (3.74)	-5.54 (3.14)	-6.19 (4.30)	-5.32 (3.50)
	Maintain (Reappraise)	-6.26 (2.87)	-7.26 (3.60)	-6.12 (2.97)	-6.97 (3.51)	-8.17 (4.53)	-7.25 (2.99)	-5.02 (2.79)	-5.59 (3.66)	-5.18 (4.05)
	Suppression	-6.76 (3.48)	-7.49 (3.85)	-6.39 (3.72)	-7.84 (4.02)	-9.59 (4.91)	-8.19 (4.13)	-5.58 (4.27)	-5.73 (4.23)	-4.87 (3.52)
	Maintain (Suppression)	-5.87 (3.32)	-6.43 (3.68)	-5.68 (3.42)	-7.08 (3.25)	-8.27 (4.10)	-6.85 (3.22)	-6.08 (4.90)	-6.33 (5.59)	-5.99 (4.48)

Appendix L Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
N2		FC3	FCZ	FC4	FC3	FCZ	FC4	FC3	FCZ	FC4
	Reappraise	-4.11 (5.68)	-5.44 (6.16)	-4.07 (4.94)	-6.57 (5.20)	-8.25 (6.23)	-6.13 (5.22)	-5.61 (5.82)	-6.67 (6.26)	-5.43 (5.03)
	Maintain (Reappraise)	-4.00 (5.48)	-5.22 (6.40)	-3.39 (4.99)	-7.08 (5.59)	-8.69 (6.71)	-6.79 (5.57)	-4.68 (5.37)	-5.30 (5.90)	-4.69 (4.79)
	Suppression	-7.48 (5.03)	-9.50 (6.05)	-7.27 (4.76)	-9.03 (5.14)	-11.54 (6.35)	-8.72 (5.72)	-5.56 (6.45)	-6.65 (7.41)	-5.21 (5.99)
	Maintain (Suppression)	-5.46 (5.13)	-6.49 (5.90)	-5.08 (5.47)	-7.32 (4.84)	-9.35 (6.54)	-7.43 (5.87)	-5.30 (5.60)	-6.51 (5.93)	-4.99 (4.67)
P3		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	Reappraise	10.76 (4.16)	11.44 (5.82)	12.11 (4.71)	10.99 (6.71)	11.54 (8.52)	12.96 (6.14)	11.96 (5.20)	11.93 (4.77)	12.96 (6.14)
	Maintain (Reappraise)	10.73 (4.54)	11.00 (6.81)	12.68 (4.63)	10.24 (6.28)	11.28 (7.23)	11.92 (5.70)	10.17 (4.05)	9.91 (4.62)	11.22 (4.90)
	Suppression	8.47 (3.63)	8.01 (4.96)	10.02 (3.78)	9.57 (6.66)	9.54 (7.90)	10.15 (6.81)	10.44 (3.99)	10.24 (4.32)	11.08 (5.23)
	Maintain (Suppression)	9.24 (4.08)	9.17 (6.31)	11.27 (4.63)	10.09 (6.74)	11.17 (8.31)	11.89 (6.57)	10.12 (4.40)	10.99 (5.15)	11.25 (5.31)

Appendix L Continued

Component (and Sites)	Condition	Early Follicular Women			Midluteal Women			Men		
LPP		P3	PZ	P4	P3	PZ	P4	P3	PZ	P4
	Reappraise	6.82 (4.71)	8.14 (5.46)	7.14 (5.32)	5.51 (4.62)	6.03 (5.95)	5.81 (4.69)	5.70 (4.50)	5.75 (4.93)	5.65 (5.05)
	Maintain (Reappraise)	6.58 (4.28)	7.46 (5.70)	6.87 (4.05)	5.09 (4.80)	5.60 (5.64)	5.72 (4.02)	4.77 (2.79)	4.55 (3.03)	4.89 (3.22)
	Suppression	5.45 (3.62)	5.82 (4.36)	5.32 (3.74)	5.45 (5.47)	5.99 (6.40)	5.59 (5.79)	5.29 (3.29)	5.33 (3.80)	4.87 (4.02)
	Maintain (Suppression)	5.83 (3.66)	6.41 (6.65)	6.22 (4.02)	5.43 (5.89)	6.03 (6.65)	6.01 (5.91)	5.23 (2.77)	5.51 (3.21)	4.73 (3.17)

Note. Standard Deviations in parentheses.

Appendix L

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Maintain (Reappraisal) and Maintain (Suppression) for Early Follicular Women, Midluteal Women, and Men for each ERP Component (Excluding Contraceptive Use).

Variable		P1			N1			N2			P3			LPP	
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	.27	.77	.007	1.99	.14	.049	2.54	.09	.061	.08	.93	.002	1.06	.35	.026
Condition	1.35	.25	.017	.06	.81	.001	4.23	.04	.051	1.02	.32	.013	.01	.97	.000
Site	2.11	.13	.026	17.12	<.001	.180	34.16	<.001	.305	11.19	<.001	.125	2.09	.13	.026
Group × Condition	.77	.47	.019	1.43	.246	.035	.42	.66	.011	1.71	.19	.042	1.21	.30	.030
Group × Site	.40	.79	.010	1.49	.21	.037	1.38	.24	.034	.84	.50	.021	.83	.51	.021
Condition × Site	.61	.52	.008	.96	.38	.012	.52	.59	.007	.35	.67	.004	.70	.48	.009
Group × Condition × Site	1.32	.27	.033	.68	.60	.017	1.52	.20	.038	1.38	.34	.028	1.60	.18	.039

Appendix L

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Reappraisal and Maintain (Reappraisal) for Early Follicular Women, Midluteal Women, and Men for each ERP Component (Excluding Contraceptive Use).

Variable		P1			N1			N2			P3			LPP	
	F	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2	*F*	*p*	ηp^2
Group	3.19	.045	.076	3.70	.03	.087	2.07	.13	.050	.01	.99	.000	1.55	.22	.038
Condition	91.88	<.001	.54	.86	.36	.011	.57	.45	.007	3.64	.07	.041	2.27	.14	.028
Site	12.69	<.001	.14	27.61	<.001	.261	33.60	<.001	.301	7.98	.001	.09	2.80	.07	.035
Group × Condition	1.42	.25	.035	.45	.64	.012	1.61	.21	.040	2.10	.13	.051	.32	.73	.008
Group × Site	3.35	.013	.079	1.28	.28	.032	1.43	.23	.035	.44	.77	.011	1.48	.21	.037
Condition × Site	15.37	<.001	.165	2.99	.05	.037	.48	.58	.006	1.22	.29	.015	1.50	.23	.019
Group × Condition × Site	1.28	.28	.032	.50	.74	.013	1.24	.30	.031	.48	.71	.012	.18	.93	.005

Appendix L

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Suppression and Maintain (Suppression) for Early Follicular Women, Midluteal Women, and Men for each ERP Component (Excluding Contraceptive Use).

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	.45	.64	.011	2.81	.07	.067	2.44	.09	.059	.46	.64	.012	.20	.82	.005
Condition	104.97	<.001	.57	1.37	.25	.017	20.15	<.001	.205	6.20	.02	.074	.68	.41	.009
Site	8.43	<.001	.098	18.22	<.001	.19	52.46	<.001	.402	9.99	<.001	.114	2.46	.09	.031
Group × Condition	.55	.58	.014	2.61	.08	.063	4.18	.02	.097	.96	.39	.024	.36	.70	.009
Group × Site	1.60	.18	.039	2.56	.05	.062	1.66	.16	.041	1.20	.31	.030	.70	.59	.018
Condition × Site	11.26	<.001	.126	1.10	.34	.014	3.16	.05	.039	7.51	.001	.088	1.21	.30	.015
Group × Condition × Site	2.07	.10	.050	1.73	.15	.042	1.27	.29	.031	.99	.42	.025	.80	.52	.020

Appendix M: Study 3 Analyses (Early Follicular and Midluteal Women Collapsed)

Appendix M

Means and Standard Deviations for Stimuli Conditions in Study 3 for Early Follicular and Midluteal Women Collapsed and Men at Relevant ERP Component Sites.

Component (and Sites)	Condition	Early Follicular and Midluteal Women Collapsed			Men		
P1		O1	OZ	O2	O1	OZ	O2
	Reappraise	7.91 (6.06)	5.45 (5.17)	7.25 (5.46)	4.69 (4.24)	4.23 (4.14)	4.92 (4.94)
	Maintain (Reappraise)	0.27 (2.08)	0.17 (1.66)	0.37 (1.74)	-0.08 (1.92)	0.26 (1.33)	0.09 (1.66)
	Suppression	7.67 (5.51)	5.39 (4.96)	6.86 (5.16)	5.30 (4.83)	5.05 (5.41)	5.48 (5.16)
	Maintain (Suppression)	-0.28 (2.29)	0.05 (1.51)	0.07 (1.86)	-0.04 (1.81)	-0.03 (1.41)	0.16 (1.61)
N1		FC3	FCZ	FC4	FC3	FCZ	FC4
	Reappraise	-6.90 (3.31)	-8.17 (3.95)	-6.82 (3.24)	-5.54 (3.14)	-6.29 (4.30)	-5.32 (3.50)
	Maintain (Reappraise)	-6.79 (3.25)	-7.86 (4.03)	-6.86 (2.99)	-5.01 (2.79)	-5.59 (3.65)	-5.18 (4.05)
	Suppression	-7.31 (3.69)	-8.58 (4.42)	-7.36 (3.92)	-5.58 (4.28)	-5.73 (4.23)	-4.87 (3.52)
	Maintain (Suppression)	-6.66 (3.23)	-7.53 (3.92)	-6.40 (3.27)	-6.08 (4.90)	-6.33 (5.59)	-5.99 (4.48)

Appendix M Continued

Component (and Sites)	Condition	Early Follicular and Midluteal Women Collapsed			Men		
N2		FC3	FCZ	FC4	FC3	FCZ	FC4
	Reappraise	-5.31 (5.70)	-6.77 (6.38)	-5.04 (5.27)	-5.61 (5.82)	-6.67 (6.26)	-5.43 (5.03)
	Maintain (Reappraise)	-5.65 (5.90)	-6.97 (6.86)	-5.10 (5.59)	-4.68 (5.37)	-5.30 (5.90)	-4.69 (4.79)
	Suppression	-8.14 (5.15)	-10.30 (6.33)	-7.82 (5.30)	-5.56 (6.45)	-6.65 (7.41)	-5.21 (5.99)
	Maintain (Suppression)	-6.38 (5.12)	-7.92 (6.42)	-6.23 (5.71)	-5.41 (5.60)	-6.51 (5.93)	-4.99 (4.67)
P3		P3	PZ	P4	P3	PZ	P4
	Reappraise	10.72 (5.68)	11.38 (7.18)	11.93 (5.74)	11.96 (5.20)	11.93 (4.77)	12.96 (6.14)
	Maintain (Reappraise)	1-.40 (5.44)	11.19 (6.81)	12.19 (5.08)	10.17 (4.05)	9.91 (4.62)	12.19 (5.08)
	Suppression	9.06 (5.32)	8.88 (6.53)	10.06 (5.51)	10.44 (3.99)	10.24 (4.32)	11.08 (5.23)
	Maintain (Suppression)	9.53 (5.60)	10.13 (7.29)	11.35 (5.67)	10.12 (4.40)	10.99 (5.15)	11.25 (5.31)

Appendix M Continued

Component (and Sites)	Condition	Early Follicular and Midluteal Women Collapsed			Men		
LPP		P3	PZ	P4	P3	PZ	P4
	Reappraise	6.06 (4.62)	6.97 (5.67)	6.36 (4.91)	5.70 (4.50)	5.75 (4.93)	5.65 (5.05)
	Maintain (Reappraise)	5.78 (4.48)	6.44 (5.57)	6.20 (3.95)	4.77 (2.79)	4.55 (3.03)	4.89 (3.21)
	Suppression	5.43 (4.58)	5.89 (5.36)	5.42 (4.87)	5.29 (3.29)	5.33 (3.80)	4.87 (4.02)
	Maintain (Suppression)	5.50 (4.83)	6.05 (5.73)	5.92 (5.01)	5.23 (2.77)	5.51 (3.21)	4.74 (3.17)

Note. Standard Deviations in parentheses.

Appendix M

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Maintain (Reappraisal) and Maintain (Suppression) for Early Follicular and Midluteal Women Collapsed and Men for each ERP Component.

Variable		P1			N1			N2			P3			LPP	
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	.03	.87	.000	2.88	.09	.034	0.81	.37	.010	.03	.87	.000	1.26	.27	.015
Condition	.65	.42	.008	.55	.46	.007	3.36	.07	.039	.39	.54	.005	.02	.87	.000
Site	1.87	.16	.022	12.39	<.001	.131	25.63	<.001	.238	7.99	.001	.089	1.05	.35	.013
Group × Condition	.29	.59	.004	2.86	.09	.034	.05	.83	.001	1.95	.17	.023	.97	.33	.012
Group × Site	.11	.88	.001	2.58	.08	.031	1.60	.21	.019	.47	.62	.006	1.17	.31	.014
Condition × Site	.18	.81	.002	.63	.53	.008	1.37	.26	.016	1.08	.33	.013	1.98	.15	.024
Group × Condition × Site	1.36	.26	.016	.14	.87	.002	2.71	.07	.032	2.29	.113	.027	2.96	.06	.035

Appendix M

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Reappraisal and Maintain (Reappraisal) for Early Follicular and Midluteal Women Collapsed and Men for each ERP Component.

Variable	P1			N1			N2			P3			LPP		
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	4.23	.04	.049	5.82	.02	.066	.10	.75	.001	.003	.96	.000	1.25	.27	.015
Condition	77.83	<.001	.487	.79	.38	.010	1.19	.28	.014	5.68	.02	.065	2.83	.09	.033
Site	7.36	.001	.082	20.49	<.001	.200	24.22	<.001	.228	6.67	.002	.075	1.22	.30	.015
Group × Condition	2.72	.10	.032	.25	.62	.003	2.63	.11	.031	4.72	.03	.054	.70	.41	.008
Group × Site	4.99	.009	.057	1.46	.24	.017	2.25	.11	.027	.72	.48	.009	1.92	.15	.023
Condition × Site	11.49	<.001	.123	3.04	.05	.036	.93	.38	.011	.58	.53	.007	1.39	.25	.017
Group × Condition × Site	2.52	.09	.030	.27	.77	.003	1.52	.22	.018	.26	.72	.003	.009	.99	.000

Appendix M

Repeated Measure ANOVA Results for Study 3 Experimental Variables and Variable Interactions during Suppression and Maintain (Suppression) for Early Follicular and Midluteal Women Collapsed and Men for each ERP Component.

Variable		P1			N1			N2			P3			LPP	
	F	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²	*F*	*p*	ηp²
Group	1.20	.28	.104	3.39	.07	.040	2.62	.11	.031	.54	.48	.006	.30	.59	.004
Condition	92.47	<.001	.530	.05	.82	.001	8.44	.003	.103	2.61	11	.031	.14	.71	.002
Site	5.95	.004	.068	13.42	<.001	.141	40.79	<.001	.332	6.66	.002	.075	2.39	.09	.028
Group × Condition	1.35	.25	.016	4.76	.03	.055	6.56	.01	.074	1.15	.29	.014	.15	.70	.002
Group × Site	2.78	.07	.033	3.45	.04	.040	1.78	.17	.021	.55	.58	.007	1.17	.31	.014
Condition × Site	6.38	.003	.07	1.17	.31	.014	1.21	.30	.015	7.12	.001	.080	.51	.59	.006
Group × Condition × Site	4.24	.02	.049	2.03	.14	.024	1.66	.19	.020	.76	.47	.009	1.48	.23	.018

Appendix N: Study 3 Analsyes (Correlations).

Appendix N

Correlations between Anxiety (DASS) and ERP Component during Reappraisal and Suppression across All Groups.

Variable	*r*	*p*
Reappraisal		
P1	.068	.54
N1	-.201	.07
N2	.021	.85
P3	-.161	.14
LPP	-.153	.17
Suppression		
P1	.108	.33
N1	-.272	.01*
N2	-.103	.35
P3	-.247	.02*
LPP	-.138	.21

Note: N=84 for all analyses; Prior to Bonferroni correction: * = p<.05; No significant correlations following Bonferroni correction were found.

Appendix N

Correlations between Progesterone and ERP Component during Reappraisal and Suppression across All Groups

Variable	*r*	*p*
Reappraisal		
P1	.202	.065
N1	-.235	.03*
N2	-.155	.16
Suppression		
P1	.046	.68
N1	-.232	.03*
N2	-.254	.02*

Note: N=84 for all analyses; Progesterone was correlated with ERP amplitudes where we observed 'Group' differences signalling a direct role of progesterone upon the obtained 'Group' findings. Prior to Bonferroni correction: * = p<.05; No significant correlations following Bonferroni correction were found.

Appendix N

Correlations between P1, P3, and LPP during Reappraisal and Suppression for Early Follicular Women, Midluteal Women, and Men.

	Reappraisal			Suppression		
	P1	P3	LPP	P1	P3	LPP
EF Women						
P1	--	-.004	-.144	--	-.082	-.059
P3	--	--	.614**	--	--	.716***
LPP	--	--	--	--	--	--
ML Women						
P1	--	.110	-.008	--	.181	.047
P3	--	--	.872***	--	--	.790***
LPP	--	--	--	--	--	--
Men						
P1	--	.357	.367	--	.277	.408*
P3	--	--	.362	--	--	.710***
LPP	--	--	--	--	--	--

Note. EF = early follicular women; ML = midluteal women; Prior to Bonferroni correction: *** = p<.001, ** = p<.01, * = p<.05; No significant correlations following Bonferroni correction.

Appendix N

Correlations between N1, P3, and LPP during Reappraisal and Suppression for Early Follicular Women, Midluteal Women, and Men.

	Reappraisal			Suppression		
	N1	P3	LPP	N1	P3	LPP
EF Women						
N1	--	.238	.424*	--	.478*	.356
P3	--	--	.614**	--	--	.716***
LPP	--	--	--	--	--	--
ML Women						
N1	--	.151	.070	--	.412*	.052
P3	--	--	.872***	--	--	.790***
LPP	--	--	--	--	--	--
Men						
N1	--	**-505****	**-.645*****	--	-.230	-.259
P3	--	--	.906***	--	--	.710***
LPP	--	--	--	--	--	--

Note. EF = early follicular women; ML = midluteal women; Prior to Bonferroni correction: *** = *p*<.001, ** = *p*<.01, * = p<.05; Bolded font=correlation significant following Bonferroni correction.

Appendix N

Correlations between P1, N1, and N2 during Reappraisal and Suppression for Early Follicular Women, Midluteal Women, and Men.

	Reappraisal			Suppression		
	P1	N1	N2	P1	N1	N2
EF Women						
P1	--	.045	-.148	--	-.357	-.121
N1	--	--	.157	--	--	.307
N2	--	--	--	--	--	--
ML Women						
P1	--	-.106	.097	--	.382*	.148
N1	--	--	.288	--	--	**.636*** **
N2	--	--	--	--	--	--
Men						
P1	--	-.467	-.290	--	.604	-.404
N1	--	--	**.741*** **	--	--	**.862*** **
N2	--	--	--	--	--	--

Note. Prior to Bonferroni correction: ***=p<.001; Bolded font=correlation significant following Bonferroni correction.

Appendix O: Data Analyses Reported in Chapters 7, 8, and 9

Appendix O

Refer to enclosed DVD-ROM disc